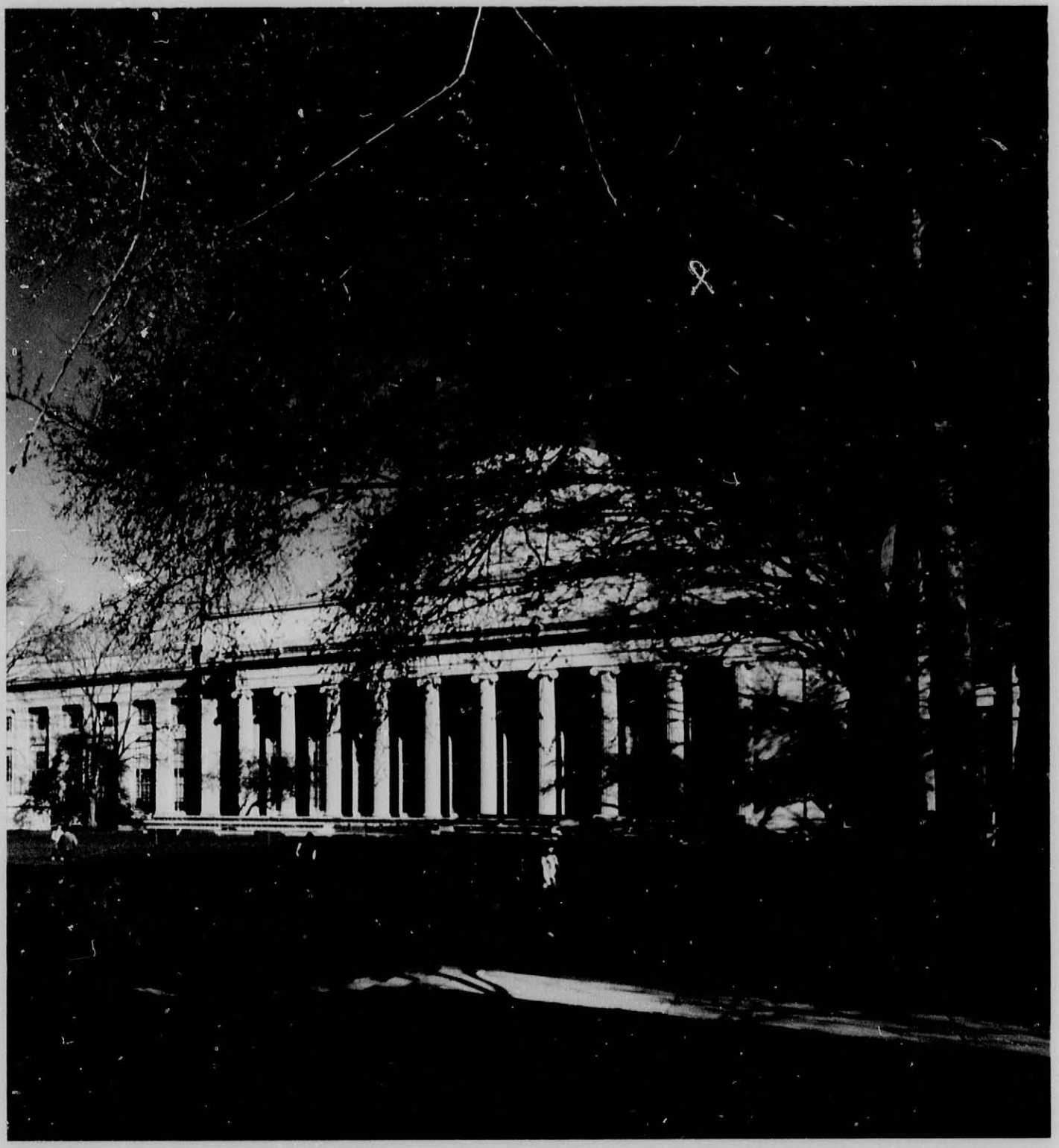
M.I.T. ANNUAL CATALOGUES AND BULLETINS
1988-89

01
OF
06

Bulletin 1988–89

Massachusetts Institute of Technology

Courses and Degree Programs Issue
1988–89



Bulletin 1988-89

Massachusetts Institute of Technology

Courses and Degree Programs Issue
August 1988

The Massachusetts Institute of Technology Bulletin (USPS 333-260) is published five times yearly by the Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, in August, December (two issues), February, and May. Issues of the Bulletin include *Courses and Degree Programs*, the *Spring Freshman Advisor and Undergraduate Seminar Programs*, the *IAP Guide*, the *Summer Session Catalogue*, and the *Fall Freshman Advisor Undergraduate Seminar Programs*.

Volume 124, Number 1, August 1988. Second class postage paid at Boston, Massachusetts, and at additional offices.

Postmaster: Send changes of address to Massachusetts Institute of Technology Bulletin, Room 4-237, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139.

The Institute reserves the right to make changes in the regulations and courses announced in this Bulletin.

The main telephone number at the Massachusetts Institute of Technology is (617) 253-1000.

The Massachusetts Institute of Technology admits students of any race, color, sex, religion, or national or ethnic origin to all rights, privileges, programs, and activities generally accorded or made available to students at the Institute. It does not discriminate against individuals on the basis of race, color, sex, sexual orientation, religion, handicap, age, or national or ethnic origin in administration of its educational policies, admissions policies, employment policies, scholarship and loan programs, and other Institute administered programs and activities, but may favor US citizens or residents in admissions and financial aid.

The Institute has adopted an affirmative action plan expressing its continuing commitment to the principle of equal opportunity in education.

Inquiries concerning the Institute's policies and compliance with applicable laws, statutes, and regulations (such as Title IX and Section 504) may be directed to Dr. Clarence G. Williams, Special Assistant to the President and Assistant Equal Opportunity Officer, Room 3-221, (617) 253-5446. Inquiries about the laws and about compliance may also be directed to the Assistant Secretary for Civil Rights, US Department of Education.

Contents

Statement of the President 5

I
This is MIT 7

An Overview 8
The Academic Program 9
The Academic Calendar 10
Educational Resources 12
The Campus 14
The Boston Environment 16
Organization of the Institute 17

II
Campus Life 19

Campus Activities 20
Housing 23
Student Services 26

III
Undergraduate Education at MIT 29

Academic Programs 30
ROTC Programs 36
Study at Other Universities 38
General Institute Requirements 40
Independent Activities Period 48
Admissions 50
Costs for Undergraduate Students 53
Financial Aid 54

IV
Graduate Education at MIT 57

General Requirements for Graduate Degrees 59
Admissions 62
Costs for Graduate Students 63
Financial Aid 66

V
Academic Procedures and Institute Regulations 69

Academic Procedures 70
Institute Regulations 74

VI
Interdepartmental Study and Research 79

VII
Departmental Degree Programs and Requirements 103

School of Architecture and Planning 104

Architecture 107
Urban Studies and Planning 112

School of Engineering 119

Aeronautics and Astronautics 122
Chemical Engineering 131
Civil Engineering 137
Electrical Engineering and Computer Science 147
Materials Science and Engineering 155
Mechanical Engineering 162
Nuclear Engineering 170
Ocean Engineering 176

School of Humanities and Social Science 182

Economics 186
Humanities 190
Linguistics and Philosophy 200
Political Science 204
Program in Science, Technology, and Society 208

Sloan School of Management 212

School of Science 220

Biology 222
Chemistry 226
Earth, Atmospheric, and Planetary Sciences 229
Mathematics 234
Physics 240
Program in Applied Biological Sciences 245

Whitaker College of Health Sciences, Technology, and Management .. 247

Brain and Cognitive Sciences 250

Additional Programs

Harvard-MIT Division of Health Sciences and Technology 254

Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution 255

VIII
Descriptions of Subjects 257

Explanatory Notes 1D
1
Civil Engineering 2D
2
Mechanical Engineering 15D
3
Materials Science and Engineering . 26D
4
Architecture 34D
5
Chemistry 48D
6
Electrical Engineering and Computer Science 51D
7
Biology 67D
8
Physics 71D
9
Brain and Cognitive Sciences 79D
10
Chemical Engineering 84D
11
Urban Studies and Planning 92D
12
Earth, Atmospheric, and Planetary Sciences 101D
13
Ocean Engineering 111D
14
Economics 119D
15
Management 127D
16
Aeronautics and Astronautics 145D
17
Political Science 155D
18
Mathematics 167D
20
Applied Biological Sciences 179D
21
Humanities 181D
22
Nuclear Engineering 210D
24
Linguistics and Philosophy 217D

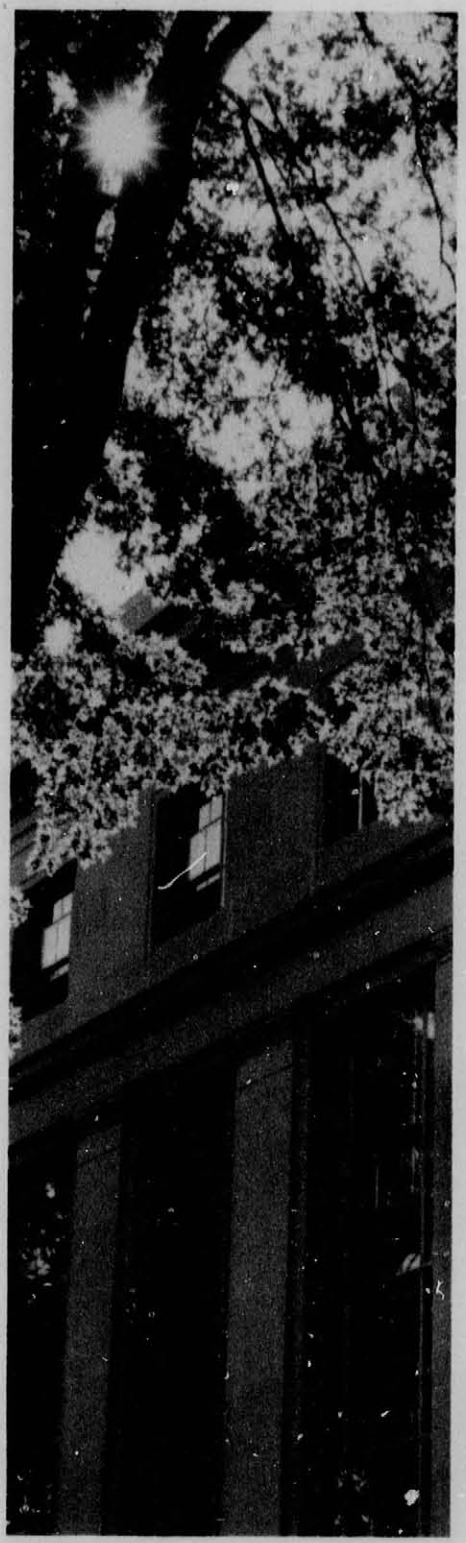
HST
Health Sciences and Technology .. 223D
SP
Special Programs 228D
STS
Science, Technology, and Society 230D
SWE
Engineering School-Wide Electives 235D
TPP
Technology and Policy 237D
AS
Aerospace Studies 238D
MS
Military Science 240D
NS
Naval Science 242D

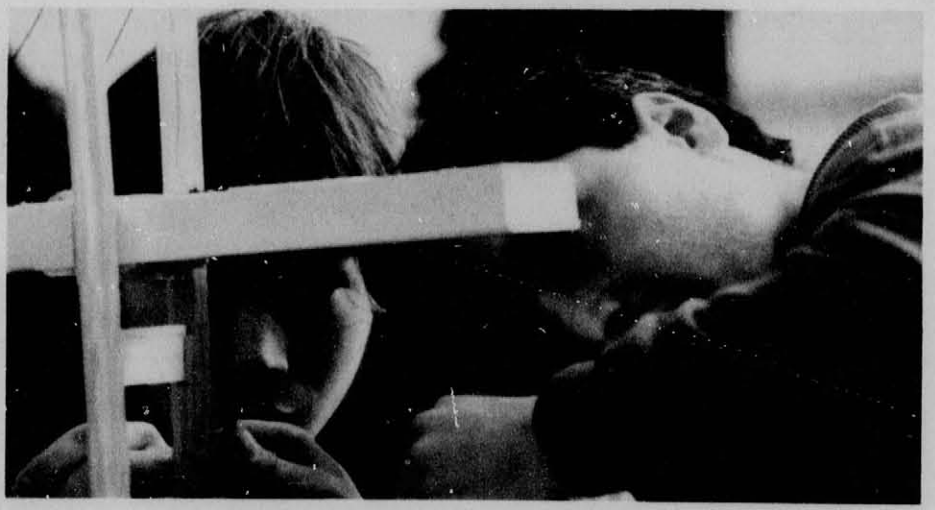
MIT Corporation 502

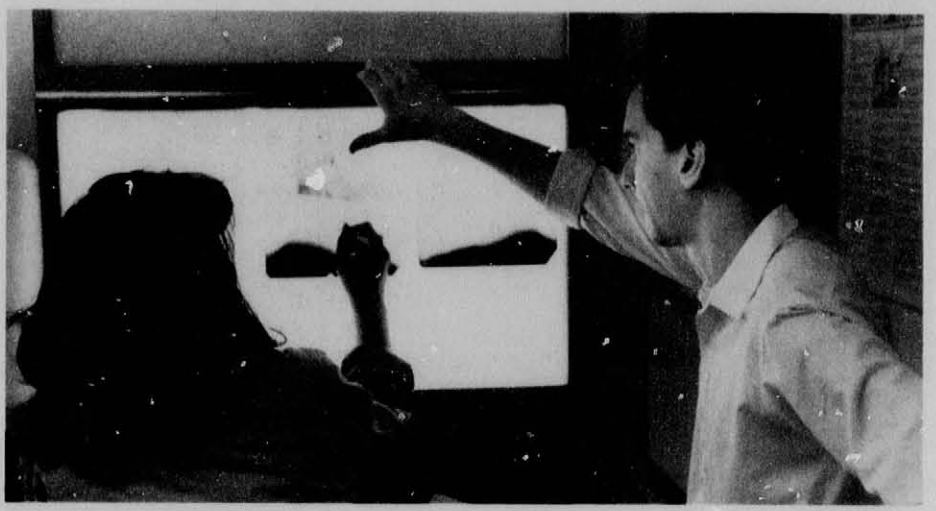
Officers of the Faculty and Institute Professors 504

Index 505

Colophon 512









An MIT Education for Our Times

Earlier in this century, people looked to science and technology to light the path of progress. This is no longer the case. That early, and somewhat naive, optimism has been replaced by a skepticism and by an alarming decline in scientific literacy in this country. This decline reflects, in part, the difficulty of keeping up with fields which grow and change with astonishing speed. But there is also, among the public, an ignorance, wariness, and discomfort about most things scientific and technological. . . .

It is clear, however, that the future development not only of this nation, but of the world, is inexorably tied to continued scientific progress and to the humane and thoughtful applications of science. What is needed is not a retreat from science and technology, but a more complete science and technology.

We must strive to develop among ourselves, among our students, and in the public at large, an understanding of the fact that engineering and science are, by their very nature, humanistic enterprises.

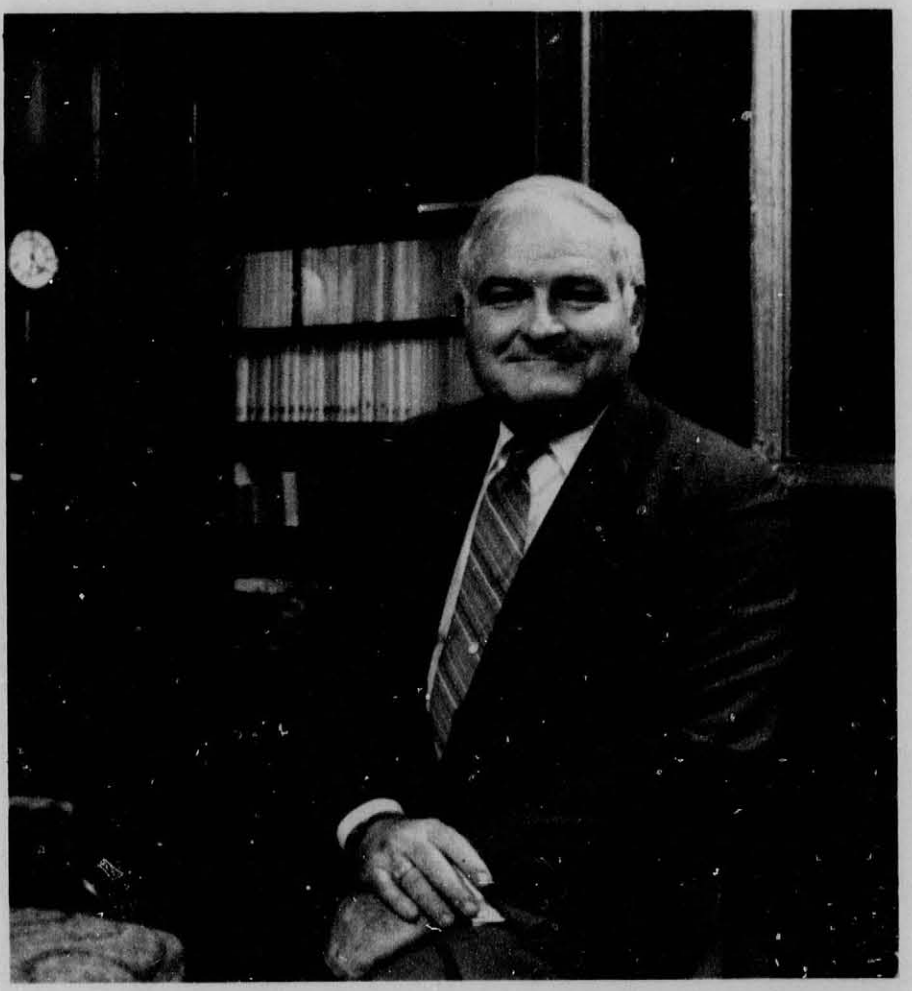
Scientific inquiry is, at once, a most natural and highly refined expression of the human mind and spirit. It is derived from native curiosity about the nature of our world and about the universe, and it results in speculations and concepts which help to give meaning and order to that world. Engineering and technology are both natural and socially derived enterprises. They offer suggestions of agenda — on goals and priorities — for scientific inquiry . . . Ultimately, I believe, this inquiry and these enterprises must rest where they begin, with concern for the human condition.

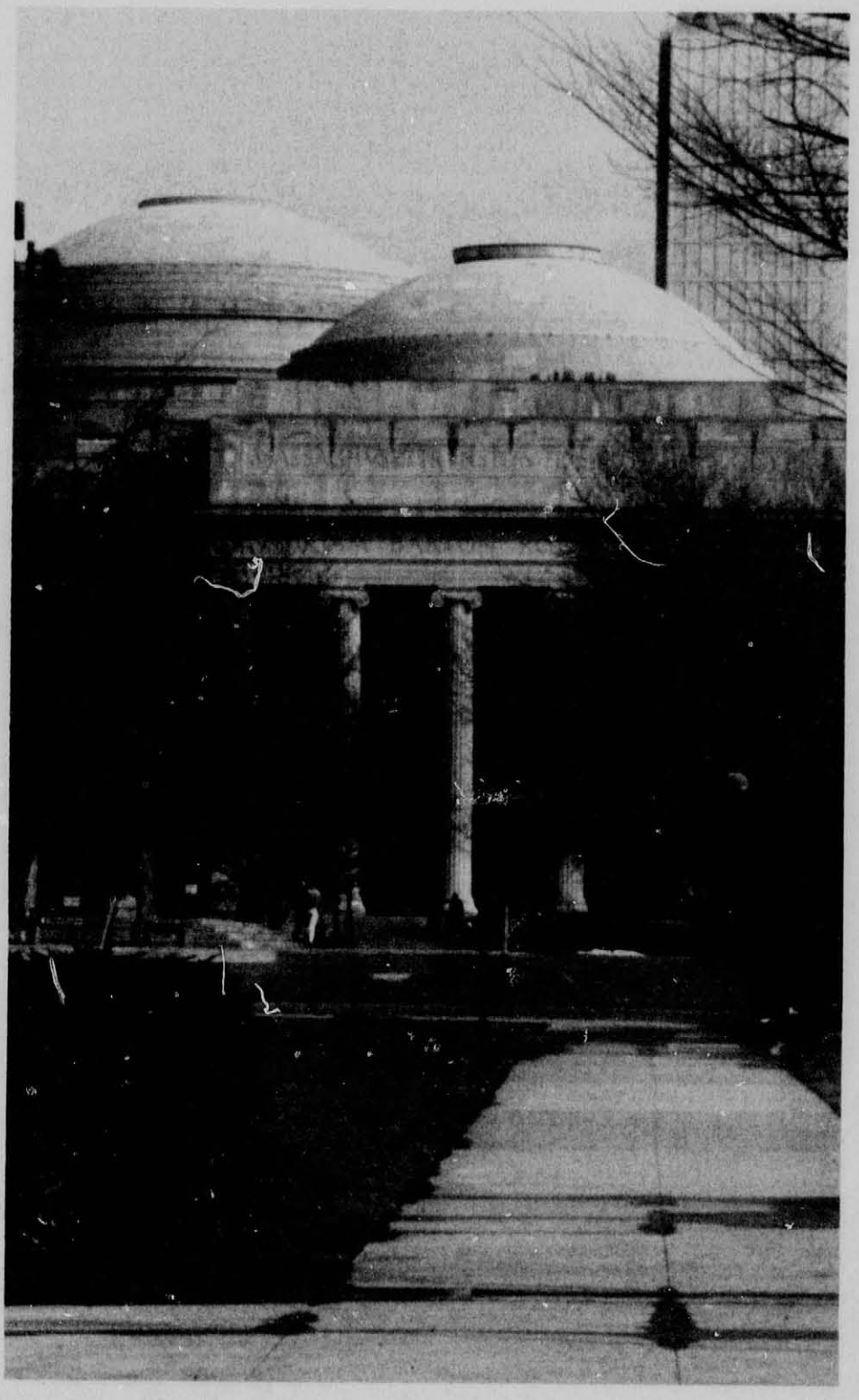
The attention to the humanistic elements and the human consequences of all that we do must be broadly shared. For, not only do we need a more complete science and technology, but we need to understand — and to engage — the larger social, cultural, and historical domains of which they are a part. We must continue to be a sanctuary for the constructive criticism of the technological enterprise and of the larger society. These principles must be built into the academic programs of our students — both undergraduate and graduate — and they must be reflected in the lives and activities of all who choose to be a part of this institution. . . .

For over a century, MIT has been a place where exceptional people from all walks of life come together to work and to study. As such, MIT has a responsibility to itself and to the nation to be open — and to reach out — to the most talented and promising people, regardless of race or sex. . . . For the sake of MIT, and for the world we help to build, we would do well to share the vision of Margaret Mead, articulated nearly 50 years ago, but no less relevant today:

If we are to achieve a richer culture, rich in contrasting values, we must recognize the whole gamut of human potentialities, and so weave a less arbitrary social fabric, one in which each diverse human gift will find a fitting place.

Paul E. Gray
President











This is MIT

An Overview

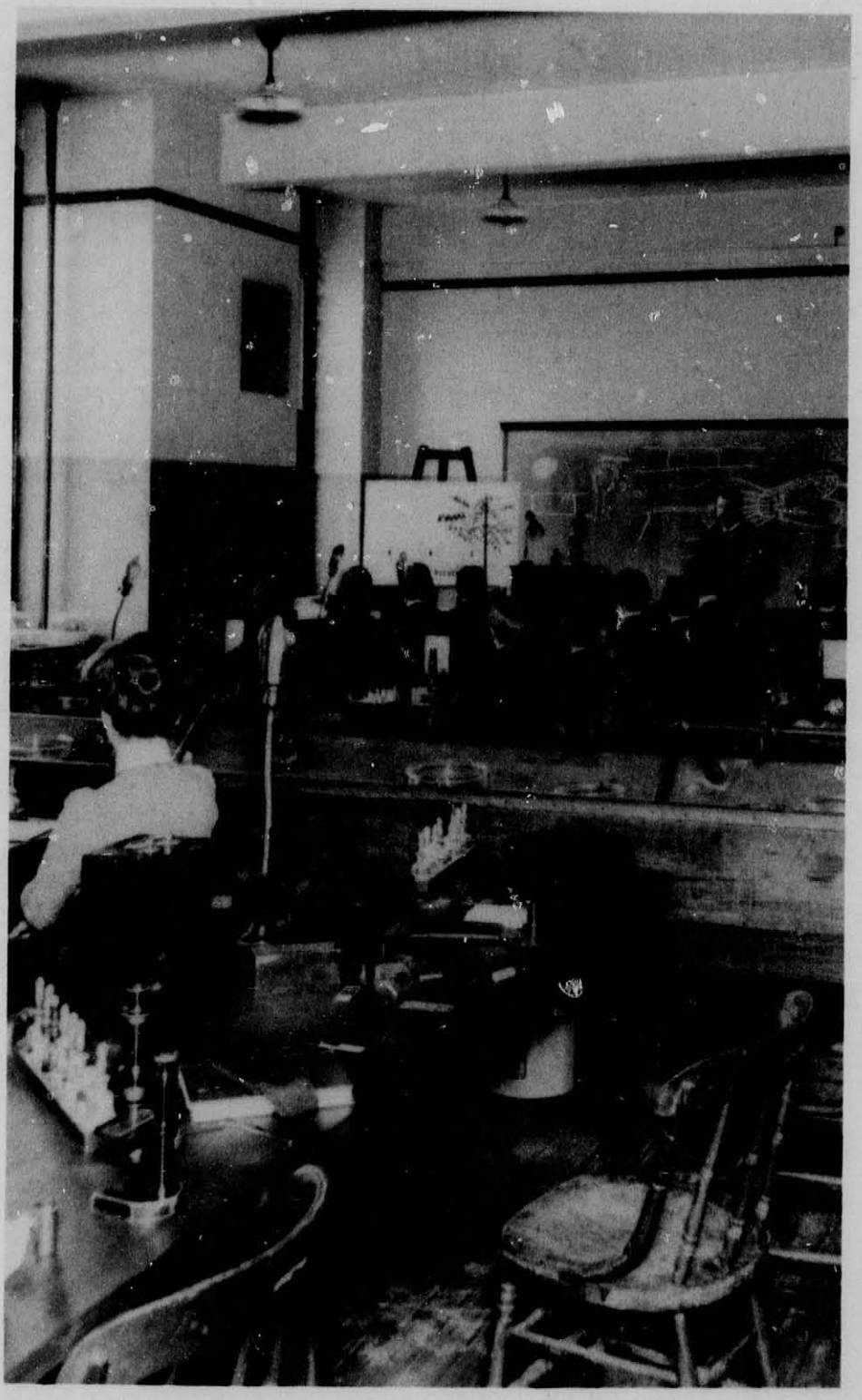
On February 20, 1865, four years after approval of its founding charter, the Massachusetts Institute of Technology opened its doors to admit the first class of 15 students. The event marked the culmination of an effort by William Barton Rogers, MIT's founder and first president, to create a new kind of educational institution relevant to the times and to the nation's need, where students would be educated in the application as well as the acquisition of knowledge. A distinguished natural scientist, Rogers stressed, too, the importance of basic research, and believed that professional competence was best fostered by the coupling of teaching and research and attention to real-world problems.

Today, education and related research continue to be MIT's central purpose, with relevance to the practical world as a guiding principle. The Institute is an independent, coeducational, privately endowed university. It is broadly organized into five academic Schools — Architecture and Planning, Engineering, Humanities and Social Science, Management, and Science — and the Whitaker College of Health Sciences, Technology, and Management. Within these Schools and the College are 21 academic departments, as well as many interdepartmental laboratories, centers, and divisions which extend beyond the traditional departmental boundaries.

MIT's total enrollment is approximately 9,500, almost evenly divided between undergraduate and graduate students. In 1987-88, MIT students came from all 50 states, the District of Columbia, two territories, and 100 foreign countries. The proportion of international students at the Institute, about 20 percent, is one of the highest in an American university.

The MIT faculty numbers approximately 1,000, with a total teaching staff of just under 1,900. Most faculty appointments are in one or more of the academic departments, but faculty members also work in the many interdepartmental laboratories, centers, and divisions. Most faculty at MIT teach both graduate and undergraduate students. Undergraduates often register for graduate classes; many undergraduates and all graduate students participate, often together, in advanced research.

This mixing of ages, disciplines, and nationalities characteristic of MIT, deeply influences the life and experience of every member of the academic community, bringing together students and teachers, biologists and architects, humanists and engineers, young and old. The result is an academic environment with a strong focus on excellence and a diverse range of interests.



The Academic Program

The purpose of the academic program at MIT is to give students a sound command of basic principles, a versatility of insight and perspective concerning natural and social phenomena, the habit of continued learning, and the power that comes from a thorough and systematic approach to learning. From these attributes comes the best assurance for continued professional and personal growth, especially in today's rapidly changing world.

The two essential parts of all MIT educational programs are teaching and research. Both of these activities carried on together have greater power than either performed alone. While advancing human knowledge and understanding, research makes special contributions to the Institute's educational program. It provides experience in both theory and experiment for students and faculty, and ensures that classroom teaching is up to date. Teaching, at the same time, provides a setting in which the relevance, accomplishments, and vitality of research are continually clarified and assessed.

Each of the 21 academic departments offers one or more degree programs or Courses[1] of study. By and large, students pursue a degree in one of the departments. Degrees are awarded on the basis of satisfactory completion of requirements in each program. Descriptions of departmental programs for graduate and undergraduate students are given in Chapter VII of this catalogue. More detailed information may be obtained by consulting the individual departments. The various Schools and Departments are as follows:

School of Architecture and Planning
Architecture
Urban Studies and Planning

School of Engineering
Aeronautics and Astronautics
Chemical Engineering
Civil Engineering
Electrical Engineering and Computer Science
Materials Science and Engineering
Mechanical Engineering
Nuclear Engineering
Ocean Engineering

School of Humanities and Social Science
Economics
Humanities (Anthropology/Archaeology, Foreign Languages and Literatures, History, Literature, and Music and Theater Arts Sections; The Writing Program)
Linguistics and Philosophy
Political Science

Sloan School of Management
Management

School of Science
Biology
Chemistry
Earth, Atmospheric, and Planetary Sciences
Mathematics
Physics
Program in Applied Biological Sciences

Whitaker College of Health Sciences, Technology, and Management
Brain and Cognitive Sciences



The academic programs of both undergraduate and graduate students are based upon a core of general Institute and departmental requirements. There is enough flexibility, however, to allow each student, in collaboration with a faculty advisor, to develop an individual program in response to his or her own interests and preparation. For example, there is a growing number of students who concentrate their studies in areas that cross departmental lines. Among these are programs in fields such as planetary and space science, communications, health sciences and technology, visual arts, transportation, urban studies, energy, and many others, which are described in Chapter VI.

Undergraduate Courses at MIT lead to the degree of Bachelor of Science (S.B.). Graduate degrees awarded include Master of Architecture (M.Arch.), Master of Science (S.M.), Master in City Planning (M.C.P.), Engineer (each degree designates the field in which it is awarded),[2] Doctor of Philosophy (Ph.D.), and Doctor of Science (Sc.D.).

For most undergraduates, degree-granting programs, including those that provide periods of on-the-job experience off campus, require four years of full-time study for the Bachelor of Science.

MIT is accredited by the New England Association of Schools and Colleges. Information about accreditation by specific professional organizations is listed within Chapter VII of this catalogue.

1
At the Institute the capitalized word **Course** refers to an organized curriculum leading to a specified degree. The lowercased word **course** or **subject,** on the other hand, refers to the individual classes. Each Course is designated by a Roman numeral; individual subjects are given Arabic numerals to correspond with the Course numbers. For example, Course II and Course II-A are curricula in Mechanical Engineering; the number 2.05 indicates a subject given in Mechanical Engineering. The Department of Mechanical Engineering as a whole can also be referred to as Course 2 or Course II.

2
Engineer degrees include Chemical Engineer (Chem.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), Engineer in Aeronautics and Astronautics (E.A.A.), Environmental Engineer (Env.E.), Materials Engineer (Mat.E.), Mechanical Engineer (Mech.E.), Metallurgical Engineer (Met.E.), Naval Engineer (Nav.E.), Nuclear Engineer (Nucl.E.), Ocean Engineer (Ocean E.).

Academic Calendar

The academic calendar provides a framework for educational programs and cultural events, and generally influences the patterns of campus life. At MIT the fall term starts shortly after Labor Day and ends before Christmas, and the spring term starts the first full week in February and ends in mid-May.

The January Independent Activities Period (IAP) provides a significant dimension to educational activities. The time during IAP may be devoted to research, study in a field of the student's interest, travel, relaxation, or investigation of new areas of interest. During this time more than 500 special activities, including films, field trips, seminars and lectures, individual projects, and intensive subjects and workshops, are offered on the campus. There are also numerous off-campus activities, including field trips and academic projects abroad.

During the regular summer session, MIT offers a selection of the subjects available during the academic year, as well as a few subjects designed for special interests and needs.



1988

August

8 Payment for first term due

12 Last day to petition for September Advanced Standing Exam and last day to go off September degree list

26 New graduate students registration material due

September

1 Freshman Residence/Orientation Week begins

5 Labor Day *(Holiday)*

6-9 Graduate Student Orientation Week

6 English Evaluation Test for International Students 9:00-12:00

6-7 Advanced Standing Exams and postponed finals

6-7 International Open House

12 Registration Day — first term

13 First day of classes

14 Alternate Registration Day — first term

30 Application for S.B. and advanced degrees in February due in Registrar's Office, E19-335. $25 fee after this date.

30 Last day to sign up for family health insurance or waive individual coverage

October

10-11 Columbus Day Vacation

14 Add Date. Last day to add subjects to registration. **Undergraduates** must petition to the Committee on Academic Performance and **graduate** students must petition to the Committee on Graduate School Policy for any add/drop after this date. $25 processing charge for any add/drop allowed after this date. Last day for juniors and seniors to change an elective to or from P/F grading.

24 Deadline for students to turn in Freshman Evaluation Forms

28 Deadline for instructors to turn in Freshman Evaluation Forms

November

11 Veterans Day *(Holiday)*

23 Drop Date. Last day to cancel subjects from Registration. **Undergraduates** must petition to Committee on Academic Performance and **graduate** students must petition to Committee on Graduate School Policy for any add/drop after this date. $25 processing charge for any add/drop allowed after this date.

23 Last day to petition for December Advanced Standing Exam (given during Final Exam Period)

24-25 Thanksgiving Vacation

December

5-6 Second-term registration material available in Building 10 Lobby

9 Last day for changing thesis title. $25 fee after this date

15 Last day of classes

15 Deadline for students to turn in Freshman Evaluation Forms

19-22 Final exam period

23 Registration material for second term due in Registrar's Office, E19-335. $25 fine for registration received after this date.

23 Christmas Vacation begins (through January 8)

1989

January

4 Deadline for instructors to turn in Freshman Evaluation Forms

6 First-term grade reports mailed

8 Christmas Vacation ends

9 First day of Independent Activities Period

9 Payment for second term due

13 Doctoral theses due for January

16 Martin Luther King, Jr.'s Birthday *(Holiday)*

20 Theses, other than doctoral, due for January

20 Last day to go on or off February degree list

20 Last day to petition for February Advanced Standing Exam

February

1 Last day of Independent Activities Period

1 English Evaluation Test for International Students 9:00-12:00

2-5 Vacation

6 Registration Day — second term

7 First day of classes

9 Grade reports for January period mailed

11 Advanced Standing Exams and postponed finals

20-21 President's Day Vacation

24 Application for S.B. and advanced degrees in June due in Registrar's Office, E19-335. $25 fee after this date.

28 Last day to sign up for family health insurance or waive individual coverage

March

10 Add Date. Last day to add subjects to registration. **Undergraduates** must petition to Committee on Academic Performance and **graduate** students must petition to Committee on Graduate School Policy for any add/drop after this date. $25 processing charge for any add/drop allowed after this date. Last day for juniors and seniors to change an elective to or from P/F grading.

24 Deadline for students to turn in Freshman Evaluation Forms

27-31 Spring Vacation

April

3 Deadline for instructors to turn in Freshman Evaluation Forms

14 Last day for changing doctoral thesis title. $25 fee after this date.

17-18 Patriot's Day Vacation

21 Summer session registration material available in Registrar's Office, E19-335

28 Drop Date. Last day to cancel subjects from registration. **Undergraduates** must petition to Committee on Academic Performance and **graduate** students must petition to Committee on Graduate School Policy for any add/drop after this date. $25 processing charge for any add/drop allowed after this date.

28 Last day to petition for May Advanced Standing Exam (given during Final Exam Period)

May

5 Doctoral theses due for second term

5 Summer Session Registration material due in Registrar's Office, E19-335

8-9 First-term registration material available in Building 10 Lobby. Reference copies of new subject descriptions available in departmental headquarters, libraries, and the Information Center.

12 Theses, other than doctoral, due for second term

18 Last day of classes

19 Last day to go on or off degree list

22-24 Final exam period

25 Registration material for continuing students due in Registrar's Office, E19-335. $25 fine for any registration received from continuing students after this date.

29 Memorial Day *(Holiday)*

June

5 Commencement Exercises

5 Second-term grade reports mailed to home address

12 Summer Session begins (through August 23 — including exam period)

Educational Resources

A special feature of education at MIT is the opportunity for students and faculty to participate together in research activities. The Institute devotes substantial resources of its own to such undertakings and receives substantial grants from both industry and government in support of such work.

MIT has unusual facilities for this research, some of which are unique among educational institutions. There are more than 70 special laboratories on the campus. In general, the Institute's policy is to make these facilities available to students — with the result that nearly all of MIT's laboratories are shared by undergraduates, graduate students, and faculty members working together in close collaboration.

Many of these research facilities are described in this catalogue by the departments which operate them. In addition to laboratories organized within departments, there is a large number of interdepartmental laboratories and centers, established to facilitate work in fields which cross the lines of traditional disciplines. Undergraduate and graduate interdepartmental opportunities and major interdepartmental organizations and research facilities are described in Chapter VI.

Information Systems (IS)

Information processing for MIT's teaching and research programs utilizes the latest developments in computer technology, including a broad spectrum of processing power from personal machines to large multiuser access systems. IS provides a full range of support services, including public terminals, documentation, education, user-consulting, and an extensive library of application and systems software. In addition, there are many local departmental and laboratory facilities which meet more specialized computing requirements, and many faculty and staff have access to personal computers. An increasing number of these computers is attached to networks which provide convenient communication among users and facilitates the distribution of computing resources.

Lowell Institute School

The Lowell Institute School was established at MIT in 1903 to provide evening instruction in technical subjects for residents of the Boston area. Today the School offers subjects in the areas of modern technology that are not readily available at other evening institutions, at a level geared to the practicing technician who has an Associate degree or equivalent experience.

The programs can broaden an individual's current skill level or prepare a technician for employment in a new field. There is strong emphasis on practical aspects, combined with sufficient theory to provide an adequate foundation of understanding.

Subjects offered by the School do not carry MIT credit, but certificates are awarded to those who complete a satisfactory program. Further information may be obtained by contacting Dr. Bruce D. Wedlock, Director, Lowell Institute School, Room E32-105, MIT, Cambridge, Massachusetts 02139.



Libraries

Supporting both the teaching and research activities at the Institute are the MIT Libraries, with holdings of 2 million volumes. More than 20,600 current journals and periodicals and extensive back files provide comprehensive resources in all major fields. These are enriched by numerous special collections, including microfiche, slides, recordings, photographs, and maps. Through MIT's membership in the Boston Library Consortium, graduate students, faculty members, and research staff have access to extensive research collections outside the Institute.

The library system, with headquarters in the Charles Hayden Memorial Library building, includes libraries for each of the Institute's five Schools and the Whitaker College, with several branches and reading rooms: the Rotch Library of Architecture and Planning (with the separate Skidmore Room for visual collections); the Dewey Library (economics, industrial management, industrial relations, and political science); the Barker Engineering Library (with a separate Aeronautics and Astronautics Library); the Humanities Library (with a Music Library and a Reserve Book Room); the Science Library (with the Lindgren Library for the earth and planetary sciences and Chemistry Reading Room); the Schering-Plough Library for the Whitaker College; the Student Center Reading Room; the Institute Archives and Special Collections; Rare Books; and the MIT Museum and Historical Collections.

All of the services offered by a fine research library are available: reference and information, interlibrary loans, bibliographic guidance, complete microfilm and photocopying facilities, and retrieval from machine-readable databases. The Libraries primarily serve Institute students, faculty, staff members, and their families. Others wishing to use the facilities may apply to the Associate Director for Public Services, Room 14S-308, for a library privilege card.

Project Athena

Project Athena is a major Institute-wide experiment to integrate computer and communications capabilities into all phases of the educational process. Athena's principal goal is to help undergraduate students learn more creatively and fully in a wide range of disciplines. To meet this goal, the project makes grants of curriculum development funds to explore the potential uses of computation in the MIT curriculum. MIT faculty, working with students, are designing software tools that will result in innovative changes in the way academic subjects are taught. During 1987-88, approximately 125 subjects used the results of these development efforts.

In large measure, Project Athena has been made possible by major grants of equipment, software, maintenance, and on-campus staff support from Digital Equipment Corporation and IBM Corporation, totalling nearly $50 million.

There are 14 public clusters on the MIT campus. The network contains approximately 700 work stations located in academic facilities, laboratories, libraries, and living groups.



The Council for the Arts at MIT

Student activities in the arts are supported through the Grants Program of MIT's Council for the Arts.

Founded in 1971, the Council is a self-supporting organization composed of 100 alumni and friends of the arts at the Institute. The Grants Program, administered by a committee, offers direct financial support to individual students, faculty, and staff, and to MIT organizations and activities. Its purpose is to stimulate and support artistic activity at the Institute. Previous experience with the arts is not necessary; experimentation, interdisciplinary projects, and broad student participation are encouraged. Grant awards range from a few hundred to several thousand dollars.

The Council for the Arts also issues a calendar of arts events taking place at the Institute and a newsletter describing particular arts activities or individuals active in the MIT arts community, and offers technical assistance in program planning and funding opportunities for artists.

MIT Press

The MIT Press, one of the country's largest university presses, publishes books and journals that enjoy worldwide circulation: professional, reference, and scholarly books; graduate and undergraduate texts; and books for general audiences. Books and journals published by the Press have won many awards, including the National Book Award, and a wide variety of citations for graphic and scholarly excellence

The Campus

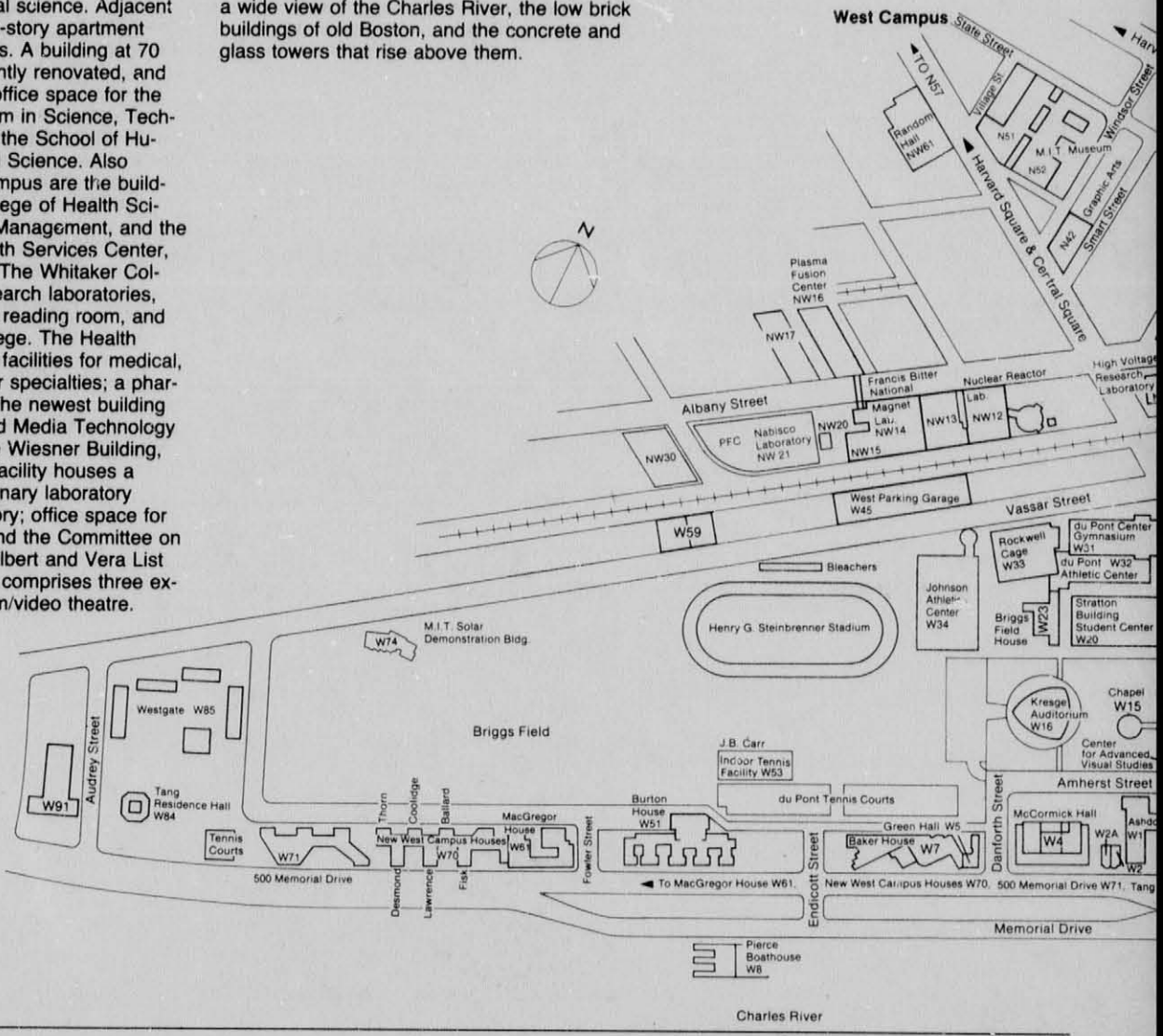
MIT's 146-acre campus extends for more than a mile along the Cambridge side of the broad Charles River Basin facing historic Beacon Hill and the central sections of Boston. Most academic activities are brought together in a group of interconnected buildings designed to permit maximum flexibility and easy communication among the departments and Schools. The extensive athletic plant and playing fields are on the campus, as are the recreational buildings, dormitories, and dining halls. This arrangement contributes greatly to the sense of unity and interdepartmental involvement that characterize the Institute.

At the eastern end of the campus are the Alfred P. Sloan Building and the distinctive Grover M. Hermann Building, which house activities in management, economics, international studies, and political science. Adjacent to them is Eastgate, a 29-story apartment tower for married students. A building at 70 Memorial Drive was recently renovated, and contains classroom and office space for the Sloan School, the Program in Science, Technology, and Society, and the School of Humanities, Arts, and Social Science. Also located on this end of campus are the buildings for the Whitaker College of Health Sciences, Technology, and Management, and the Medical Department Health Services Center, completed in early 1982. The Whitaker College Building houses research laboratories, classrooms, a library and reading room, and headquarters for the College. The Health Services Center provides facilities for medical, dental, surgical, and other specialties; a pharmacy; and an infirmary. The newest building on campus is the Arts and Media Technology facility, also known as the Wiesner Building, completed in 1985. This facility houses a newly created interdisciplinary laboratory called the Media Laboratory; office space for the Council for the Arts and the Committee on the Visual Arts; and the Albert and Vera List Visual Arts Center, which comprises three exhibition galleries and a film/video theatre.

A commanding feature of East Campus is McDermott Court, in which a great sculpture by Alexander Calder rises in bold contrast to the facade of the 20-story Center for Earth Sciences, the Cecil and Ida Green Building. Surrounding McDermott Court are student residences, Walker Memorial (which houses a dining hall and snack bar, the graduate student pub, and student activity offices), Hayden Library, the Camile Edouard Dreyfus Chemistry Building, and the Ralph Landau Building, which houses the Department of Chemical Engineering.

The Institute's main buildings, enclosing the Killian Court, were designed by Welles Bosworth, Class of 1899, and were dedicated in 1916. Banked by rhododendrons and lined with tall shade trees, the Killian Court opens to a wide view of the Charles River, the low brick buildings of old Boston, and the concrete and glass towers that rise above them.

Interconnected with these central buildings are the Center for Life Sciences (the Dorrance and the Whitaker buildings), the Karl Taylor Compton Laboratories (electronics and nuclear science), the EG&G Education Center (with lecture and laboratory facilities for the Department of Electrical Engineering and Computer Science), the Center for Materials Science and Engineering (the Vannevar Bush Building), the Center for Space Research (the Ronald McNair Building), the Sloan Laboratory, the Guggenheim Laboratory, and the Center for Advanced Engineering Study.



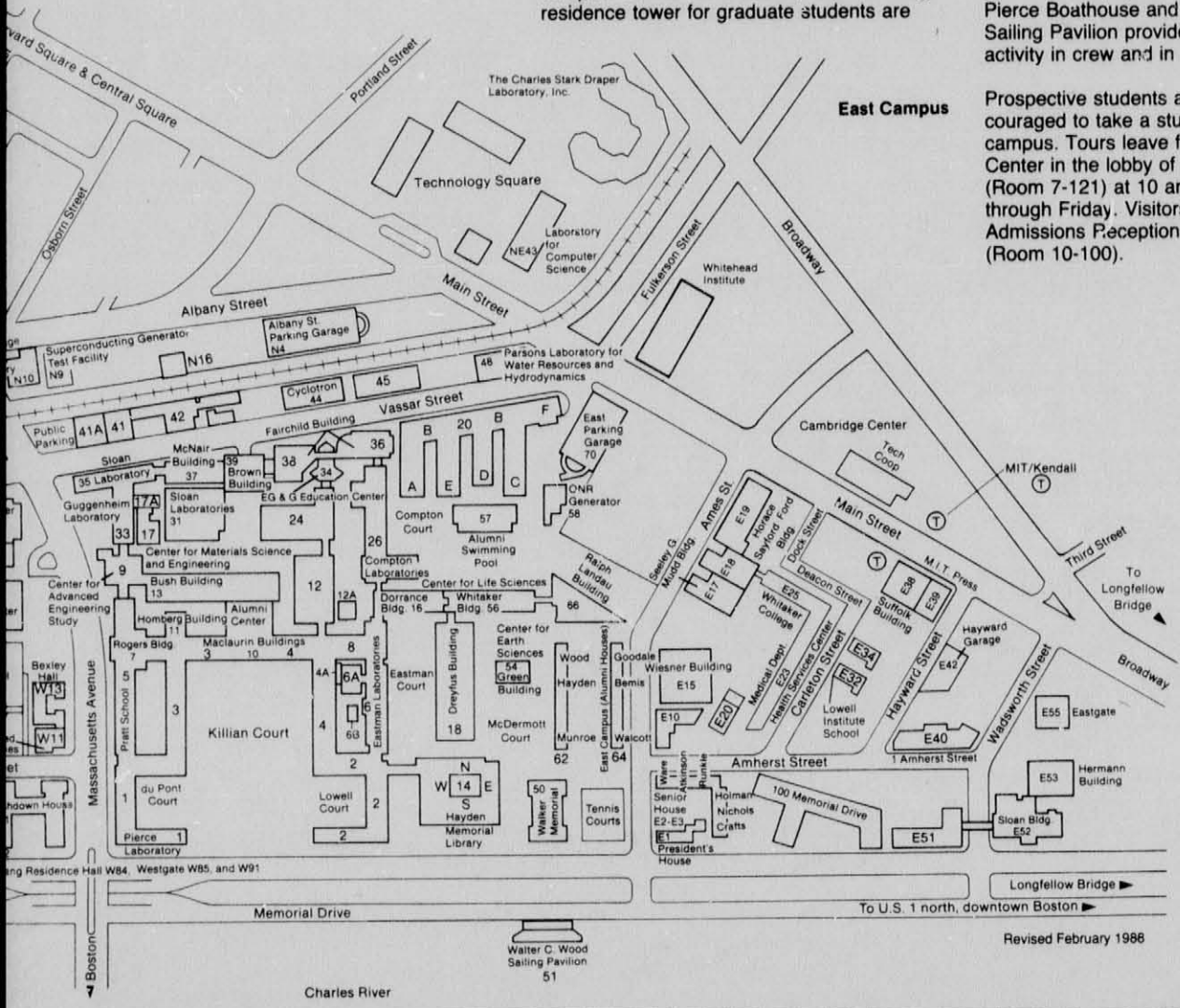
Across Massachusetts Avenue, on West Campus, is the Student Center (the Julius Adams Stratton Building), which contains social rooms, cafeterias, offices for student activities, music rooms, a spacious reading room, and recreational and commercial facilities. The Student Center Plaza is bounded on the west by Kresge Auditorium and on the east by the Chapel. Both buildings were designed by Eero Saarinen. The auditorium contains a large concert hall seating 1,200, a little theatre, offices, and rehearsal rooms. The Chapel is used regularly for religious services by all faiths and is open throughout the day for meditation. The Chapel's unusual design includes an exterior moat that reflects light in changing patterns on the interior walls. Adjacent to the Chapel is the Center for Advanced Visual Studies.

Located throughout the campus is an outstanding collection of contemporary environmental sculpture including works by Henry Moore, Louise Nevelson, Alexander Calder, Pablo Picasso, and Tony Smith. This collection highlights the history, art, and architecture of the Institute.

Along Memorial Drive and facing out on the Charles River are additional student residences, among them the serpentine Baker House, which was designed by the Finnish architect Alvar Aalto. Westgate, an apartment complex for married students, and the Tang residence tower for graduate students are located at the western-most end of the campus. Also on West Campus are the du Pont Athletic Center and playing fields for soccer, lacrosse, baseball, softball, touch football, rugby, cricket, track, and tennis. The Howard W. Johnson Athletics Center includes an indoor ice rink and field house, and Rockwell Cage accommodates varsity and intramural basketball, volleyball, and badminton. MIT's Steinbrenner Stadium includes a six-lane, 400-meter, all-weather running track, the first of its kind in North America. The Stadium also includes facilities for the steeplechase and field events, with a game field inside the track oval for intercollegiate football, soccer, lacrosse, and field hockey games.

The Charles River Basin, which is two miles long and a third of a mile wide, is a major feature of MIT's physical environment, and the Pierce Boathouse and the Walter C. Wood Sailing Pavilion provide means for extensive activity in crew and in sailing.

Prospective students and their families are encouraged to take a student-guided tour of the campus. Tours leave from the Information Center in the lobby of the Rogers Building (Room 7-121) at 10 am and 2 pm Monday through Friday. Visitors are welcome at the Admissions Reception Center after the tour (Room 10-100).



Revised February 1988

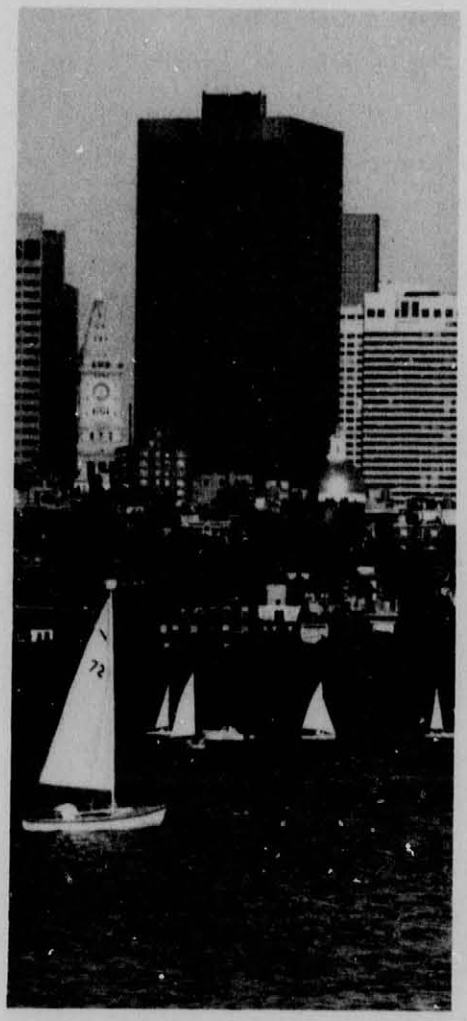
The Boston Environment

MIT is in Cambridge, Massachusetts, on the north bank of the Charles River, facing the city of Boston. The city of Cambridge, best known as the residence of MIT and Harvard, is home to many students and young professionals, especially near the two campuses. The city also has a strong ethnic character with tightly knit Portuguese, Italian, and Irish neighborhoods.

Within a two-mile radius of the Institute are the Museums of Science and Fine Arts, the Gardner Museum, the New England Conservatory of Music, Symphony Hall, the New England Aquarium, and the Boston Public Library, as well as Fenway Park and Boston Garden — arenas for professional baseball, basketball, and hockey games. Students can travel easily to the theatre district where pre-Broadway plays are previewed and local productions are staged. Among the numerous cultural organizations in the area are the Boston Symphony Orchestra, the Boston Pops, the Boston Ballet Company, the Opera Company of Boston, the Boston Center for the Arts, Boston University's Huntington Theatre Company, the Loeb Drama Center, and the American Repertory Theatre.

MIT is one of more than 50 schools located within the Boston area. Others include Harvard University, Radcliffe College, Boston University, Northeastern University, Boston College, Brandeis University, Tufts University, Simmons College, Wellesley College, and many specialized professional art and music schools. The concentration of academic, cultural, and intellectual activities in the Boston area is one of the largest in the country, and there is an extraordinary variety of young people, over 250,000, from all over the country and the world.

An hour or two away from MIT by car are the mountains of Vermont and New Hampshire, the ocean beaches of Cape Cod, the lakes and rivers of Maine, the small clusters of fishing towns along the New England coast, and many places of historical interest — Salem, Sturbridge, Lexington, Concord, and Plymouth — in Massachusetts alone. The four distinct seasons of New England, combined with the varied landscape, offer unlimited possibilities for recreation — skiing, mountain climbing, hiking, sailing, canoeing, kayaking, swimming, and camping.







Organization of the Institute

The Institute's board of trustees is known as the Corporation, over which the Chairman presides. Its members include approximately 75 distinguished leaders of science, engineering, industry, education, the professions, and public service, and (ex officio) the President, Treasurer, and Secretary of the Corporation. Between quarterly meetings, the Corporation functions through its officers and Executive Committee.

The Corporation appoints Visiting Committees for each department and for certain of the other major activities at the Institute. These Committees, whose members are leaders in their respective professions, provide counsel to the departments and in turn make recommendations to the Corporation concerning departmental activities.

The Institute's chief executive officer is the President. In addition, senior administrative officers of the Institute include the Provost, the Associate Provosts, and Vice Presidents. The Provost is the senior academic officer and has Institute-wide responsibilities for academic programs in education and research. In this capacity, the Provost works closely with the Associate Provosts and the Deans, each responsible for the undergraduate and graduate programs in one of the five academic Schools. The Institute's 21 academic departments, each under the leadership of a department head, are organized within the five Schools and the Whitaker College.

The President presides over the faculty of the Institute, which consists of all professors, certain professors emeriti, and a number of administrative officers (ex officiis). Officers of the faculty are the President of the Institute, and the Chair, the Associate Chair, and the Secretary of the Faculty.

The Academic Council is responsible for the overall administration of the Institute. This group consists of the senior officers, the vice presidents, the deans, the Chair of the Faculty, and the Director of Libraries. Department heads and directors of laboratories and centers join them to form the Faculty Council.

Educational policy for the Institute is determined by the faculty. The MIT faculty meets monthly and conducts much of its business through a number of elected standing committees. The Faculty Policy Committee (FPC), which includes student members, maintains a broad overview of the Institute's academic programs, deals with a wide range of policy issues of concern to the faculty, and coordinates the work of the faculty committees. The Chair of the Faculty chairs the FPC.

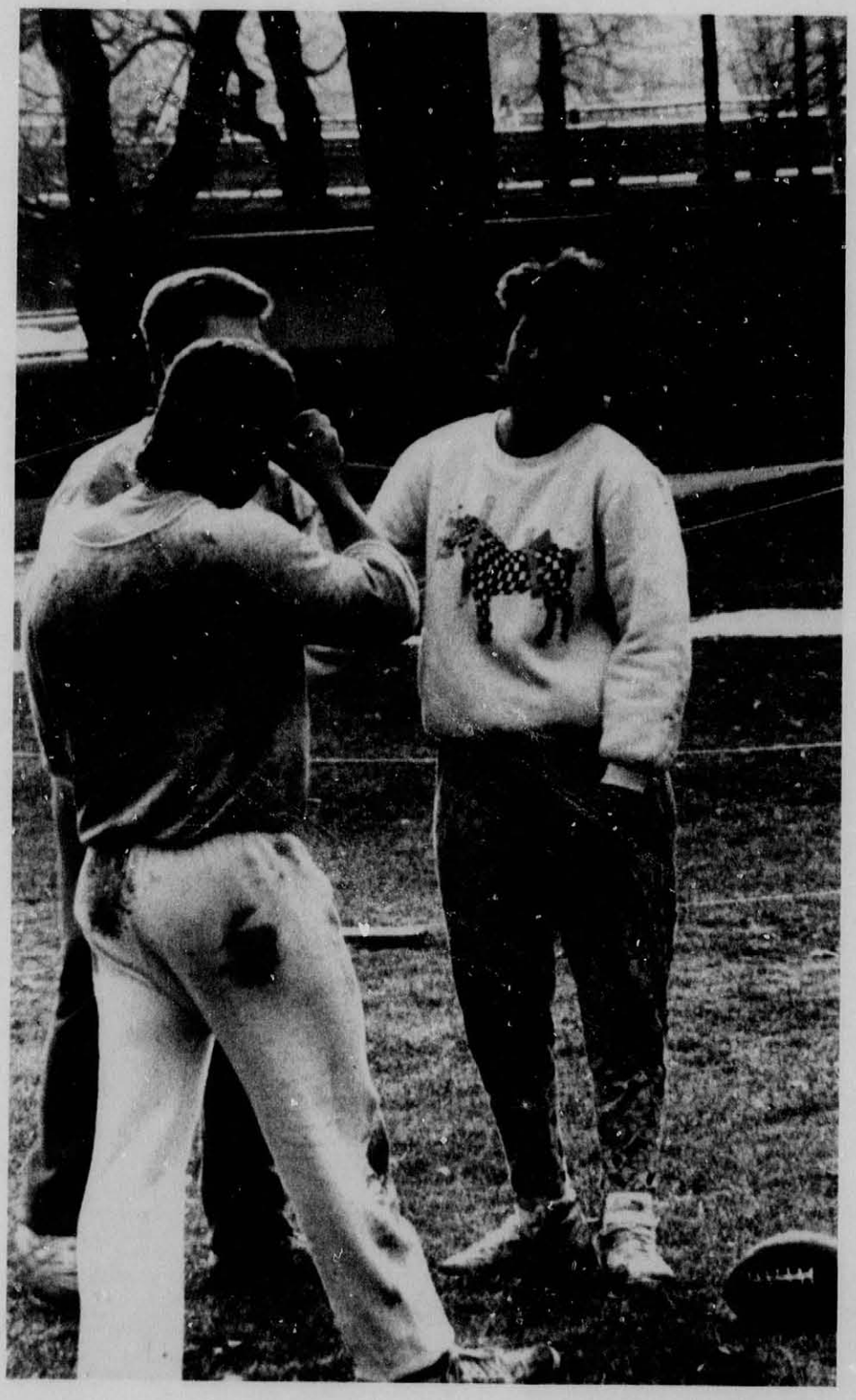
The Dean for Undergraduate Education has responsibilities in appraising undergraduate education at MIT and giving impetus to new directions and efforts. The Dean of the Graduate School is concerned with coordinating educational policies of the graduate programs, and the Dean for Student Affairs is directly concerned with all aspects of student life.

The management of research activities, which are financed through contracts with government and industry, is supported by the Office of Sponsored Programs. The Industrial Liaison Program provides industry and other organizations access to research resources at MIT and a means of exchanging information with their MIT counterparts. Through the Program, technological developments made at MIT are transferred to industry for commercial application, helping to link work at the Institute to the solution of societal problems.

The MIT Alumni Association has a comprehensive program for keeping some 86,000 men and women, who have studied at MIT, informed of Institute affairs. For example, the Alumni Association publishes *Technology Review,* a nationally circulated journal of contemporary affairs in science, architecture, engineering, humanities, management, and other fields represented among MIT alumni. There are nearly 75 regional MIT clubs throughout the world. The Alumni Fund, through which alumni contribute to the financial mainstream of the Institute, ranks annually among the country's most successful. Alumni activities include conferences, class reunions, and seminars in Cambridge and major cities throughout the United States, as well as a program of communications and directories.

The Association of MIT Alumnae is an organization of former MIT women students with a continuing interest in women currently studying at the Institute. The group maintains and administers its own funds for special financial aid to women students.














10
51

Campus Activities

There is much more to an MIT education than study and research in classrooms and laboratories. Over 200 activities and services are available which complement strictly academic pursuits, and provide numerous opportunities for students to grow and develop new interests. This chapter describes the range of activities on campus; the Institute's housing and dining programs; and the advisory, counseling, and medical services available to students.

Undergraduate Student Government

The MIT Undergraduate Association, to which all undergraduates belong, is the major undergraduate governmental body. It is assisted by a variety of committees. The Finance Board coordinates budgets and allocates funds to student organizations. The Student Center Committee helps manage the facility, develops programs, and operates a 24-hour coffeehouse. The Student Committee on Educational Policy proposes educational reforms, while the Course Evaluation Guide activity publishes a review of courses offered at the Institute. It also provides student feedback to the departments and the Institute on important educational issues. The Student Information Processing Board operates free computer services for student use and advises on computer policy at the Institute. The Association of Student Activities coordinates programs, recognizes new activities, and allocates space. The Nominations Committee recommends student representatives for more than 50 faculty and administrative committees. The Social Committee produces the major social events of the year, such as autumn and spring weekends.

The International Students' Association represents the interests of international students at the Institute and sponsors a newsletter, assemblies, and other events.

All living groups, both fraternities and Institute Houses, elect governing councils, responsible for the functioning of their houses. In addition to sponsoring social events, these house councils handle most judicial matters within the respective houses. To deal with problems of common concern, the fraternities have joined in the Interfraternity Conference (IFC), while the Institute Houses have formed the Dormitory Council. The IFC operates a central food purchasing agency, coordinates and supervises Rush Week, and works to improve relations between fraternities and Boston's Back Bay community by sponsoring an area clean-up and beautification program. The Dormitory Council coordinates common house activities such as freshman orientation, major social events, and handles inter-house judicial problems.

Each class at MIT annually elects a president and executive committee to handle various class activities.

Graduate Student Government

All graduate students are represented by the Graduate Student Council. The Council comprises elected representatives of all Courses, Ashdown House, Tang Hall, Green Hall, Eastgate, Westgate, international students and at large members. The Council organizes and encourages social, academic, athletic, cultural, and other extracurricular activities; promotes closer relations between graduate students and faculty outside formal academic exercises; and voices ideas and suggestions of graduate students. The Graduate Student Council has five committees which meet at least monthly and the Council itself meets monthly. The Graduate Student Council nominates two students to serve on the faculty Committee on Graduate School Policy, one student to the Faculty Policy Committee, and has representation on several other standing committees of the Institute. As a service to the graduate student community, the Council also produces a monthly newsletter entitled *The Graduate Student News.*The location is Building 50-222, Walker Memorial, above the Muddy Charles Pub.

Athletics

Athletics and recreation play an important role in the lives of many students at MIT, and the Institute encourages everyone to participate in some type of program. Instruction is available in a wide variety of activities, many of which are considered lifetime sports.

Last year, approximately 800 men and women were active in intercollegiate varsity sports while other students, seeking more informal activities, joined club and intramural teams. The popular intramural program regularly attracts more than two-thirds of the undergraduates and a significant number of graduate students. Last year, there were 1,180 teams with an estimated 11,779 total participants. In addition, MIT's sailing program attracts another 1,500 students, faculty, staff, and alumni, and extends sailing privileges to their families.

MIT sponsors varsity sports for men in baseball, basketball, crew (heavyweight and lightweight), cross country, fencing, golf, gymnastics, indoor and outdoor track, lacrosse, pistol, rifle, sailing, skiing, soccer, squash, swimming, tennis, volleyball, water polo, and wrestling. In addition, there are women's varsity teams in basketball, cross country, crew, fencing, field hockey, gymnastics, sailing, skiing, soccer, softball, swimming, tennis, and volleyball. Competition includes New England colleges and some Ivy League schools. Club varsity sports include football and men's ice hockey.



There are intramural programs in backgammon, badminton, basketball, bowling, chess, cross country, cycling, fencing, football, frisbee, hockey, pool, sailing, soccer, softball (fast and slow pitch), squash, swimming, table tennis, tennis, track (indoor and outdoor), volleyball, water polo, weight lifting, and wrestling.

There are 34 club sports including archery, badminton, contemporary dance, figure skating, ultimate frisbee, judo, karate, women's lacrosse, rugby (men and women), graduate soccer, table tennis, white-water kayaking, and canoeing.

MIT's excellent facilities include the Howard W. Johnson Athletics Center (with an indoor track and ice hockey rink), the du Pont Athletic Center, Alumni Swimming Pool, Wood Sailing Pavilion, and Pierce Boathouse. The 20-acre Briggs playing fields include the du Pont outdoor tennis courts, nine softball diamonds (two with lights), and a multipurpose Omniturf synthetic surface. The J. B. Carr Tennis Center includes four indoor courts. Rockwell Cage was renovated to accommodate varsity and intramural basketball, volleyball, and badminton. Steinbrenner Stadium features a 400-meter all-weather track, one of the best in the nation.

Lectures, Seminars, and Films

The Lecture Series Committee (LSC) is a student-run organization which brings outstanding and controversial speakers to the campus. LSC also has cosponsored, with MIT departments or other campus groups, events of cultural, entertainment, or educational significance. The LSC is financed by its program of classic and current films. Films are also presented by campus nationality groups and the Student Center Committee.

Religious Organizations

There are currently 16 active and long-standing student religious organizations on campus which are based in the Chapel and the Student Center. Ministers representing the major faiths devote all or a large part of their time to on-campus activities, counseling individual students, and advising student religious organizations.

In accordance with the Chapel's interdenominational status, the Institute has not appointed an Institute Chaplain or Dean of the Chapel. MIT considers that one of its responsibilities is to maintain an atmosphere of religious freedom for all and to provide opportunity for the exercise of all spiritual interests.

Student Publications

Student publications at MIT include *The Tech,* a student newspaper published twice weekly; *Technique,* the senior yearbook; *Rune,* an annual literary magazine; *How to Get Around MIT (HowToGAMIT)*; and *The Graduate Student News,* a publication of the Graduate Student Council. Students may also contribute their talents to the Institute House newspapers and to a variety of departmental and organizational newsletters.



Special Interest Groups

There are more than 150 cocurricular activities and clubs at MIT (many of them open to both faculty and students), including the Outing Club, The Tech Sports Car Club, the Speech and Debate Society, the FM local broadcasting station (WMBR), the MIT Society for Women Engineers, and the Student Art Association.

Many students are actively engaged in social service work in the Greater Boston area. Groups such as the Interfraternity Conference and Alpha Phi Omega, the national service fraternity, sponsor active social service programs.

In addition, MIT also has a variety of clubs geared towards students' backgrounds and lifestyles. The MIT Black Student Union (BSU) runs a variety of programs in education, culture, and black students' issues. The over 30 international student groups on campus sponsor many programs, including discussion groups and social events. MIT has an active organization of gays, called Gays at MIT (GAMIT), which organizes weekly awareness programs and discussion groups, and sponsors social events throughout the year. The Technology Community Women (TCW), is composed of wives of MIT students, both undergraduate and graduate, and sponsors a variety of monthly programs as a social and service organization.

There is a variety of dance activities and clubs at MIT. The Folk Dance Club, the Tech Squares, the Ballroom Dancing Club, and various foreign student groups provide regular opportunities for dancers at all levels of ability. The M'T Dance Workshop presents formal programs and supervised instruction as well as sponsors periodic special courses by professional dancers from the Boston area.

Smaller interest groups include bridge, chess, model rocket, railroad clubs, strategic games, and numerous others. Information can be obtained in the student government office in the Student Center.

Technology Community Association (TCA)

Managed by undergraduates, TCA conducts a diversified program of year-round services to the MIT community, including a book exchange, silkscreening facilities for student use, and blood donor drives. TCA also channels volunteers into urban community service projects.

Theatre

A variety of theatrical performances is presented on the campus by both student organizations and professional groups.

Dramashop is a student drama group which functions under the supervision of the Director of the Drama Program, and includes a set and a costume designer and a technical director. Each year this group presents at least two major productions of full-length plays and several workshop productions of one-act plays directed, designed, and acted by students. Further information on the Drama Program may be found under the School of Humanities and Social Science.

The Musical Theatre Guild presents two major and two smaller-scale musical productions each year. All cast and crew members are volunteer, and MIT students are given first priority in filling all manager, director, designer, orchestra, cast, and technical positions.

The MIT Community Players includes graduate students, as well as undergraduates, faculty, staff, and their families. Each year they present, under professional direction, three full-stage productions — two during the academic year and one during the summer.

The MIT Shakespeare Ensemble, composed of MIT and Wellesley students and a professional director, presents two main productions each year and maintains an extensive repertory of scenes. The Ensemble tours its fall production throughout the Northeast and also performs at Boston-area high schools and institutions. The Ensemble also conducts an apprentice program that offers training in Shakespearean acting.

In addition, a few undergraduate living groups on campus occasionally produce and present musical theatre performances.

Music

MIT is a musical community. It has a busy season of musical activities and programs performed by many different musical groups, all of which are open to both undergraduate and graduate students. These groups include the Symphony Orchestra, Concert Band, Chamber Music Society, Festival Jazz Ensemble, Concert Jazz Band, and Gospel Choir. There are also two a capella groups, the Logarhythms (an all-male vocal club), and a coed popular-music group, the Chorallaries. The Choral Society, which draws its 150 members from the entire MIT community, performs both classical and contemporary choral works.

These organizations give public concerts on the campus, participate in joint concerts on other northeastern college campuses, and take periodic concert tours throughout the East and Midwest.

Chamber music groups, symphonic groups, and concert soloists appear at the Institute each year as part of the Humanities Series entitled Music at MIT. Additional chamber music concerts given by faculty and students are regularly scheduled throughout the year. Other professional musical events are sponsored at the Institute by various campus organizations.

Committee on the Visual Arts

The Committee on the Visual Arts administers a variety of programs intended to increase understanding and appreciation of contemporary art and design. Exhibitions, events, artist residencies, and other special projects take place within, or originate and expand from, three galleries in the new Albert and Vera List Visual Arts Center. The Catherine N. Stratton and List Student Loan collections provide prints on loan to students for the academic year following an exhibition each September. The MIT Permanent Collection of paintings, sculpture, drawings, prints and photography is sited in offices and public spaces throughout the Institute and is particularly noted for outdoor sculpture and contemporary works on paper.

Educational activities include tours, lectures, interdisciplinary events, and an extensive publications program in conjunction with List Visual Arts Center activities.

The MIT Museum

The MIT Museum collects and preserves materials associated with MIT history, presents exhibitions, and sponsors educational programs. The Museum maintains two on-campus galleries, the Hart Nautical Galleries and the Margaret Hutchinson Compton Gallery, in addition to its main facility at 265 Massachusetts Avenue.

The Hart Nautical Collections maintain a fine exhibition of paintings, prints, photographs, ship plans and models, and working drawings of yachts and small craft by well-known 20th-century designers.

Exhibitions in the Compton Gallery illustrate the Institute's programs and fields of inquiry. Exhibitions at the main facility include a broad range of materials related to the MIT community in general and to the relationships among science, art, and technology in particular

Talbot House

Talbot House, an old New England farmhouse in South Pomfret, Vermont, is administered by the Office of the Dean for Student Affairs. It was a gift by Laurance Rockefeller to be used by the MIT community.

The atmosphere at Talbot House is relaxed and comfortable. Meals are prepared by a staff cook and served family style. Members of the MIT community take advantage of the tranquility at Talbot House to retreat from the hectic pace of city life. The most frequent visitors to the house have been members of clubs, living groups, and academic groups. Some groups have gone for recreation and a study break; others have found Talbot House to be an excellent setting for special projects, seminars, workshops, or research discussions.

Any group from the MIT community, ranging in size from 15 to 27 people, may request the use of Talbot House. A number of considerations is weighed in determining which groups can be accommodated.

Housing

Undergraduate Single Student Housing

At the undergraduate level, MIT is essentially a residential university. Of the total undergraduate student body of 4,500, about 2,700 single men and women live in the ten Institute Houses on the campus, and about 1,350 single men and women are in other residence groups including 31 fraternities, the cooperative MIT Student House, and the Women's Independent Living Group. Limited housing is available for transfer and readmitted students.

The central purpose of the residential system is to provide an environment conducive to personal development as well as academic achievement. The Institute relies greatly on the initiative and responsibility of both individual students and student government organizations in the residences.

Faculty families chosen for their understanding of and deep interest in students live in each of the Institute Houses. They are not charged with formal academic or operational responsibilities; instead, they welcome informal associations with their fellow residents. In all of the Institute Houses and in some fraternities, Graduate Residents also provide personal and academic assistance to undergraduates.

With the exception of McCormick Hall (all female), the Institute Houses have coeducational living facilities. Most of the coed Houses also have "single-sex" living areas within the House. Although we are unable to guarantee the assignment of a freshman to a particular House or to a single-sex area, every effort is made to assign students to one of their top choices.

Student governing groups establish and administer House regulations and maintain acceptable standards of community behavior. Residential student governments also organize a wealth of social, athletic, and intellectual programs for House members. In the Institute House system a tax determined by the residents of each House is collected by MIT and turned over to the House government to help support these activities. Individual fraternity chapters have similar charges to support their extracurricular programs.

The Institute believes that it is to the great advantage of all undergraduates who do not live at home to reside "on campus" — that is, to live in an Institute House, one of the 31 fraternity residences, the Women's Independent Living Group, or the MIT Student House. Freshmen particularly gain from associations with upperclass students and participation in residence programs. Therefore, all unmarried freshmen who cannot commute daily from their own homes or those of close relatives in the Greater Boston area are required to live on campus. Exceptions to this on-campus living requirement may be made with the approval of the Associate Dean for Student Affairs.

Institute Houses

Everett Moore Baker House

Bexley Hall

Burton-Conner

East Campus Houses — Munroe, Hayden, Wood, Goodale, Bemis, and Walcott

Frank S. MacGregor House

Stanley McCormick Hall

New West Campus Houses — Ballard, Lawrence, Coolidge, Desmond, Fisk, and Thorn, which include:

French House
German House
Russian House
Spanish House

Random Hall

Senior Houses — Ware, Atkinson, Runkle, Holman, Nichols, and Crafts

500 Memorial Drive

Rooms in the Institute Houses are engaged for the full academic year. For the year 1988-89, the average rents for the Houses range from $1,036 to $1,347 per term.

A student cancelling a room assignment after the stated deadline of July 8 will be charged a cancellation fee. A student withdrawing from MIT during a regular term will receive a refund based on proration of the term rental over 15 weeks of occupancy.

Meal Plans for 1988-89

The meal plans for all MIT students, graduate and undergraduate, provide a wide range of options, flexibility, and financial equity.

MIT Food Services offers the following Student Meal Plans for 1988-89.

If you live in one of the four houses with a dining room, you will need to purchase a House Plan. This includes Baker, MacGregor, McCormick, and 500 Memorial Drive residents. However, the 1988-89 House Plan is one price, $623 per term for all underclass House residents.



Meals at MacGregor, McCormick, and 500 Memorial Drive are purchased on the ongoing A La Carte House Plan basis. Students on this plan can also use their cards at any of the cash locations on campus including, the Student Center, 500 Memorial Drive Snack Bar, Walker and Pritchett Lounges, the Bagel Wagon, the Cookie Cart, Cafe 13 and Networks.

Meals at Baker House are provided on a House Plan that charges the fixed prices indicated below for breakfast, lunch, and dinner for a choice of entree, vegetables, and desserts. All beverages, salad bars, soups, and breads are included in this House Plan total meal price.

Breakfast	$2.50
Lunch	$3.85
Dinner	$5.85

Students can buy an additional entree by using their Vali-Dine card on an a la carte basis, and also use their card at any of the cash locations mentioned above.

Students living in other houses or off campus, can purchase this House Plan described above, or purchase an Open Plan. The price for an Open Plan is $250 per term.

All students wishing to increase their balance in any of the plans may do so at any time in $50 increments and can use either plan to purchase meals at the House dining rooms, or for a la carte purchases at any of the MIT Food Services on campus. An $800 per term plan is available to all students wishing to save the time involved in periodically increasing their balance.

Students will be able to use their plans during IAP. Unused balances for plans other than those with House dining rooms will be refunded.

Detailed information about the dining plans, their use during IAP, the options available, the minimum requirements, refunds, and how to use the program is available in the *Undergraduate Residence* book and in the Food Service Vali-Dine Office in Room E18-375.

Fraternities, Sororities, and Independent Living Groups

MIT recognizes a total of 35 fraternities, sororities, and independent living groups. Twenty-five of these are nationally affiliated fraternities, two are local, five are coed — one of which is a co-op based on financial need (Student House) — one is all female, and two are currently unhoused nationally affiliated women's fraternities (sororities). These groups are dispersed in the Boston, Brookline, and Cambridge communities. The Interfraternity Conference (IFC) represents these groups in the MIT community.

Each fraternity, sorority, and independent living group, is self-governing, manages all of its operations and maintenance, and develops its academic, social, membership, recreational, and external policies and programs. These living situations provide a unique experience in leadership, community planning, and group interactions.

Approximately 95 percent of the fraternity, sorority, and independent living group freshmen are pledged during "Residence/Orientation Week," which is held in September just prior to registration. Normally, about 375 freshmen, as well as a few upperclassmen and transfer students, accept invitations to join these groups.

The Women's Independent Living Group

The WILG is a non-dormitory living group for women in a renovated residence a short distance from campus. The living group offers a sense of community and allows for independence and self-governance similar to the fraternities. WILG is also a member of the Interfraternity Conference.

Cooperative Living

The MIT Student House is an independent, coeducational, cooperative living group for financially needy students. It is owned by a corporation of House alumni. The 30 undergraduate members maintain the residence and do all the work except for major repairs. Students cooperate in the management of the House and the academic, recreational, and social aspects of student life. Savings per member are at least $800 a year. Student House is also a member of the Interfraternity Conference.

Off-Campus Student Housing

Students who do not live on campus will find help in locating accommodations in the Off-Campus Housing Service. Listings of available rentals in the Greater Boston area are maintained. The staff attempts, on an individual basis, to help students locate the type of accommodations that will best suit individual preferences and finances. All correspondence should be addressed to Off-Campus Housing Service, Building E32-121, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139.

Additional Information

Additional information on undergraduate housing and application procedures is contained in the publication *Undergraduate Residence at MIT*. Each first-year student is automatically sent a copy of this brochure about three months before registration day of the term for which he or she has been admitted to MIT. Others may request copies from the Office of the Dean for Student Affairs, Room 7-139, MIT, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139, (617) 253-4051. Information about fraternities also may be obtained by writing to Interfraternity Conference, Room W20-413, MIT, Cambridge, Massachusetts 02139. Information on the MIT Student House may be obtained by writing to the President, MIT Student House, 111 Bay State Road, Boston, Massachusetts 02215.



Graduate Single Student Housing

Approximately 30 percent of the single graduate students reside on the campus in Avery Allen Ashdown House, Ping Yuan Tang Residence Hall, and Ida Flansburgh Green Hall. Except during the summer, students must be registered for each semester in order to reside in on-campus student housing.

Ashdown House

Ashdown House, located on the corner of Massachusetts Avenue and Memorial Drive, directly across from the main buildings of MIT, houses 415 single graduate men and women in single, double, and triple rooms.

A member of the faculty, who is familiar with the aims and problems of graduate students, resides with his or her family in the House, serving as the Faculty Family in Residence. A student House Executive Committee, acting with the advice and assistance of the Faculty Resident, plans and operates the activities program. Ashdown House, with facilities for social and cultural events, is a center of graduate student activities.

Rooms in Ashdown House are rented for a full academic year; rents range from $2,320 to $2,712 per person for the academic year, depending on the type of room.

Green Hall

Opened in the spring of 1983, Green Hall accommodates 46 single graduate women in 32 single and eight double rooms. The completely refurbished dormitory is centrally located on Memorial Drive within five minutes walking distance of the athletic and Student Centers, and the main campus buildings.

Rooms are furnished with a bed, desk, chair, lamp, and dresser, and range from $2,300 to $2,552 per person for the academic year. Rooms in Green Hall are rented for the full academic year beginning September 1 and include all utilities except private telephone.

An MIT faculty family resides in the Hall and assists student leaders in planning social and orientation activities. Community cooking facilities are available on each floor, or residents may purchase meals on a charge plan or a la carte in nearby McCormick Hall.

Tang Hall

Tang Hall, located on the far western end of the campus, houses 404 single graduate men and women in two-, three-, and four-bedroom apartments. The apartments, unfurnished except for wall-to-wall carpeting, drapes, and kitchen appliances, are rented on a 12-month license to each occupant, beginning September 1. Rents range from $249 to $295 per occupant per month and include all utilities except telephone. Community facilities are available in this building, two tennis courts are located nearby, and limited parking is available nearby at a nominal annual fee.

More complete information on all graduate residences may be found in *A Practical Planning Guide for New Graduate Students,* which is automatically mailed to all entering graduate students.



Married Student Housing

Residence in married student housing is limited to regular undergraduate and graduate married students registered and attending MIT whose spouses are present in the residence, and to single parents with at least one child in residence. Except during the summer, students must be registered for each semester in order to reside in on-campus student housing. Assignments are made on a one-year license-agreement basis beginning on September 1 of each year. Apartment rents range from $507 to $755 per month and include all utilities except telephone.

Married student housing is managed by the MIT Housing Office, Room E32-200, MIT. Since accommodations in Eastgate and Westgate are limited, married students seeking apartments also are advised to contact the Off-Campus Housing Service.

Westgate

This five-building complex, located at the west end of the MIT campus, provides 209 apartments for married student families.

Westgate consists of a 16-story tower with 90 one-room efficiency apartments and 60 one-bedroom units, and four three-story garden-type buildings with a total of 59 two-bedroom apartments.

Eastgate

Located adjacent to Kendall Square at the east end of the MIT campus, Eastgate is a 29-story apartment tower with 197 family units for married students.

In the tower building there are 94 one-bedroom apartments, 84 larger one-bedroom apartments, and 19 two-bedroom apartments.

Student Services

Advising and Counseling

The Institute offers a variety of advising and counseling resources. By intention, they are not centralized in a "counseling center." A student is free to choose the resource that appears to be most helpful. Counseling, as the word is used here, refers to casual conversations and to scheduled appointments; it ranges from the providing of information to skilled psychotherapy.

The *Freshman Handbook* and *How to Get Around MIT* list in detail the counseling resources at MIT. Only a short summary is given here. Each student has a faculty advisor. The Office of the Dean for Student Affairs/Student Assistance Services offers counseling services to all students, whether the situation is academic or personal or both. The office has special responsibilities for international students, women, minorities, and handicapped students. Faculty and graduate residents and tutors are available in the Institute Houses, and some fraternities have graduate residents. Frequently, a student is able to get the help he or she wants from a fellow student or from an instructor who is not officially a faculty advisor. Coaches and activity advisors can be helpful as well.

Several offices specialize in particular areas. They include the Student Financial Aid Office, which includes student employment; the Religious Counselors; and Career Services and Preprofessional Advising. The Campus Police are frequently of help to students. For students considering particular fields, there is a Premedical Advisory Council, a Prelaw Advisory Council, and a Foreign Study Advisor.

The services provided by the Medical Department are described next. The psychiatrists, psychologists, and social workers from the Medical Department are considered by many students to be among the Institute's most skilled counselors.

Medical

The MIT Student Health Program consists of medical services available on campus and a hospital insurance plan in which all regular students are automatically enrolled unless they submit a written request to waive coverage.

Medical Services On Campus

The MIT Medical Department is a multispecialty group practice that employs 23 full-time and 40 part-time physicians as well as other professional support personnel. The Department's medical staff provides care in internal medicine, surgery, pediatrics, gynecology, obstetrics, orthopedics, ophthalmology, optometry (including contact lens services), urology, allergy, neurology, nutrition, endocrinology, dermatology, otolaryngology, gastroenterology, pathology, podiatry, radiology, psychiatry, and social work. The Department provides a pharmacy as well as laboratory, X-ray, and other diagnostic testing facilities. A health education service and a patient advocate are also available. A major goal of the Department is to provide high-quality, accessible medical care. Students are encouraged to choose an internist as a personal physician to coordinate their health care. Under a new program, some students will be assigned a personal physician.

A dental service provides dental treatment to students and their spouses on a fee-for-service basis. A pediatric service provides care for students' children on a fee-for-service basis. Except for emergencies, visits are by appointment.

An 18-bed Inpatient Service provides care for students and spouses with acute illness or contagious diseases. This service is for patients who cannot be cared for in their living groups but who do not need to be admitted to a general hospital. Children are not admitted to the Inpatient Service but are referred to a nearby pediatric hospital. Patients requiring major surgery or treatment for serious illness are sent to one of the Boston-area hospitals where their care is usually supervised by one of the Medical Department physicians.

Visits to the Medical Department are by appointment, except in emergencies. The regular hours of the Department are from 8:30 am to 5 pm, Monday through Friday, except for holidays. At all other times, urgent medical care is available through the After-Hours Service on the first floor of the Health Services Center. Students should call 253-1311 day or night for medical advice. If a student is too ill to come to the Health Services Center without assistance, the Medical Department should be notified and will recommend suitable help.

All regular and special students are entitled to most health care services at the Health Services Center (Building E23) at no charge. Students will be billed for completion of pre-entry medical forms and immunizations, obstetrical care, routine eye examinations, elective podiatry, contact lens services, hearing aid evaluations, ear piercing, dental care, missed appointments, contraceptive devices, prescription drugs, and those surgical procedures that should be covered by the student's hospital insurance policy. Student spouses may use the Department by paying for each visit, or receive the same benefits as a student by paying the $402 Health Service fee for coverage from September 1, 1988 through August 31, 1989. (Off-campus medical services are not covered unless authorized in advance by the MIT Medical Department.)

Prior to matriculation, every student, undergraduate or graduate, is required to submit an MIT entrance medical form. The form, which is completed by the student and his or her personal physician, is returned to the chief of the Student Health Program. This form consists of historical information, immunization record, physical examination, and specified laboratory studies. Freedom from active tuberculosis as evidenced by an intradermal skin test or chest X-ray is mandated by public health requirements and cannot be waived. By state law or Medical Department requirements, students must be immune to measles, rubella (German measles), mumps, polio, tetanus, and diphtheria before arriving at MIT. If a student has not returned the pre-entry physical form by the time he or she enters MIT, the student will be required to have a physical examination by the Medical Department staff. There will be a charge for this service and for any required immunizations and laboratory tests.



Office of Career Services and Preprofessional Advising

MIT Student Blue Cross and Blue Shield Hospital Insurance

The cost of off-campus hospitalization and medical care is extremely high — in Boston-area hospitals, it exceeds $700 per day. For this reason, it is extremely important that students have adequate health insurance for themselves and their families. All regular students will be automatically enrolled and billed for **individual membership** in the MIT Student Blue Cross and Blue Shield plan. Students who want **family coverage** must submit a new enrollment form each academic year. Students who already have equivalent hospital insurance may submit a Waiver Request Form, enclosed in the July Medical Department mailing and also available in E23-308. New waiver request forms must be filed each academic year. Non-US citizens must submit a copy of their insurance policy to the Student Health Program Office (E23-308), together with the completed waiver request.

Special students taking two or more courses are eligible to purchase the MIT Student Blue Cross and Blue Shield, but are not enrolled automatically.

Annual Rates (September 1, 1988 - August 31, 1989)

	MIT Medical Department	MIT Student Blue Cross and Blue Shield Plan
Student	included in tuition	$336
Spouse	$402 or fee for service	$1,038
Child(ren)	fee for service	$336

The Office of Career Services and Preprofessional Advising serves students seeking information, advice, or counseling on employment, opportunities for further study, and careers.

The Career Services staff is happy to talk with students on an individual basis about their plans. The Office also arranges seminars at which alumni and others discuss the rewards and frustrations of their own career fields. The Office maintains a comprehensive library containing information on careers, specific employers in industry and government, courses of graduate study, fellowships, and opportunities for work and study abroad. In addition, information on premedical and prelaw studies, as well as other details about professional postgraduate education, is available.

A wealth of information is available on job opportunities for minority students. The Office is a cosponsor, along with the Admissions Office, of the Pathway to the Future Program for students from underrepresented minority groups.

More than 400 companies, government agencies, and graduate schools make recruiting visits to the Office each year. These visits are publicized in descriptive notices that are posted throughout the Institute. All bona fide employers are given access to the facilities of the Office on equal terms. Their coming to the campus gives students a valuable opportunity to discuss employment prospects with different organizations.

Students who are unclear about their career plans are also encouraged to come in. Doubts, worries, and questioning are often a natural part of career planning, and the counseling component of the Office can assist in addressing these issues.

The Office, through its Alumni Placement section, is in continual correspondence with employers seeking experienced personnel. Notices of vacancies are received from all parts of the nation and abroad. The Office also assists alumni interested in a change of job or of career.

These services and others are described in the *MIT Careers Handbook,* which the Office publishes twice a year. Students are welcome to come by and pick up a copy.

Any individual with career interests, questions, or concerns should call (617) 253-4733 or stop by Room 12-170.

Child Care Services

The Child Care Office helps families with young children locate suitable child care arrangements. There are three programs operating on the MIT campus that can accommodate children from infancy to age five. All of the programs reflect the great diversity of cultures that one finds at the Institute.

Family Day Care is organized by the Child Care Office and is an arrangement in the home of a day care provider who has been licensed by the Commonwealth of Massachusetts. Each family day care home operates independently, offering its own attitudes and activities. The Child Care Office puts providers and users in touch with each other. Actual arrangements are made by the families involved. Fees range from $3.00 to $4.00 per hour. Family day care homes are located in Eastgate and Westgate, as well as in other parts of Cambridge and surrounding communities.

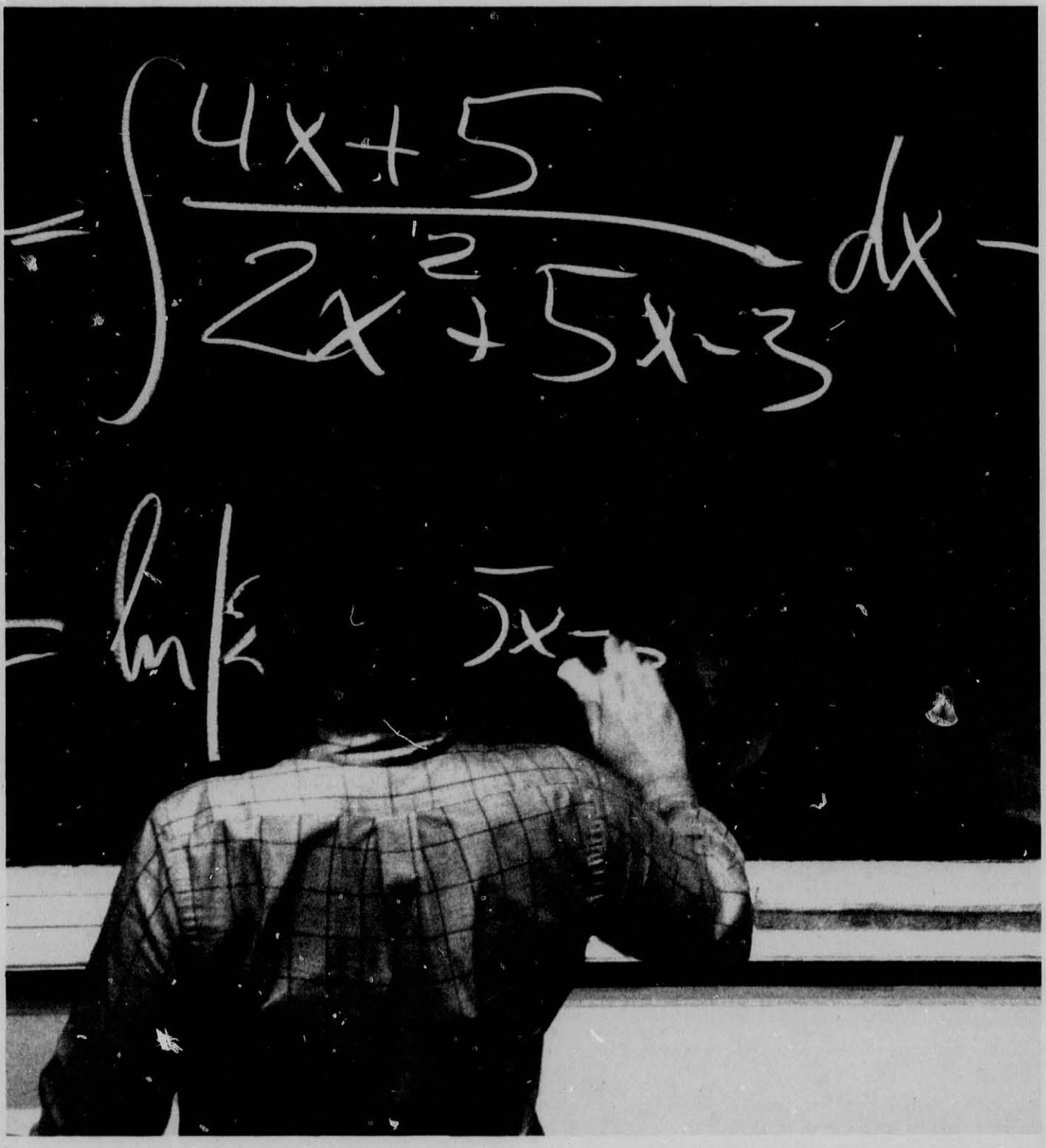
Technology Children's Center, Inc. (TCC) is a private, nonprofit corporation that operates two programs on campus for children who are at least two years and nine months old:

The Half-Day Program at Eastgate follows the academic calendar and offers a morning program from 8:30 am to 1 pm. Children may be enrolled for two, three, or five mornings a week. Monthly fees for the 1988-89 school year are $300 for five mornings, $195 for three mornings, and $130 for two mornings. There is also an eight-week summer program.

The program at Westgate offers a full-time, year-round morning program from 8:30 am to 12:30 pm, combined with extended day hours from 12:30 pm to 3:30 pm Monday through Friday. Children may be enrolled for two, three, or five mornings a week. Monthly fees for the 1988-89 school year are: for five mornings $275, for five afternoons, $185; for three mornings $180, for three afternoons, $110; and for two mornings $120, for two afternoons $75.

The Day Care Program offers full-time, year-round care from 8 am to 5:30 pm, Monday through Friday. The center is located at Eastgate. The monthly fee for 1988-89 is $585.

The Child Care Office maintains information about child care in other parts of Cambridge and surrounding communities. Every effort is made to find the arrangement that is most suitable for an individual family. Further information may be obtained from the Child Care Office, Room 4-144, MIT, Cambridge, Massachusetts 02139, (617) 253-1592, or TCC, 60 Wadsworth St., Cambridge, Massachusetts 02142, 253-5907.


$= \int \frac{4x+5}{2x^2+5x-3} dx -$
$= \ln|$

III Undergraduate Education at MIT









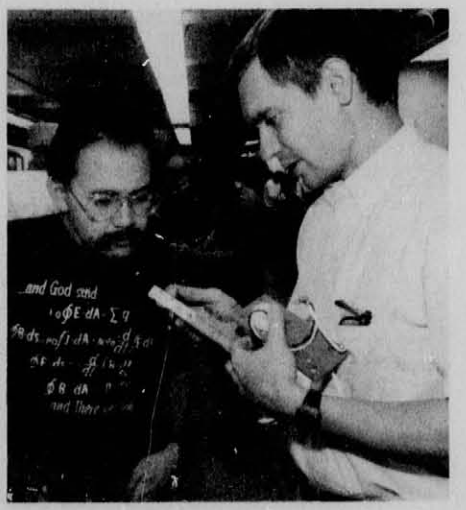
Academic Programs

The Freshman Year

The undergraduate programs at MIT are designed to help students develop the understanding, maturity, and capabilities needed to meet the challenges of modern society. An MIT education has its roots in a wide variety of disciplines, with a view to joining the power of these disciplines with a concern for human values and social goals. In addition to taking advantage of the opportunities for broad, liberal learning at MIT, undergraduates are encouraged to develop a basic knowledge and a continuing interest in a given field, and to become creative intellectual explorers who know how to keep learning on their own.

One of the most exciting features of undergraduate education at MIT is the opportunity for students to join with faculty in ongoing research projects. Such experiences, through the Undergraduate Research Opportunities Program (UROP), encourage intellectual commitments and self-direction, and often provide a focus for students' undergraduate studies. There is also an Independent Activities Period each January during which students can spend time in workshops, independent research projects, intensive subjects and seminars, field trips, lecture and film series, and other activities that do not easily fit into the traditional academic calendar.

MIT students base their studies on a core of subjects in science, mathematics, and the humanities, arts, and social sciences (the General Institute Requirements), and major in the physical or life sciences, in management, in architecture or urban studies and planning, in an area in the humanities or social sciences or in one of the engineering fields. It also is possible to study and even major in one of a growing number of interdepartmental fields, such as energy studies, biomedical engineering, communications science, humanities and engineering, and humanities and science. In the first year, many students take a program of subjects from a variety of options in mathematics, physics, chemistry, and humanities. During the second year, students generally continue their studies with subjects meeting the various Institute requirements and with the beginning subjects in the departmental programs. In the third and fourth years, students concentrate on the departmental program that they selected as their major Course of study.[1]



In addition to the departmental or major program, there is time for students to take elective subjects each year. These elective opportunities allow students to follow special interests or to enrich their educational background. A student may also use elective time to prepare for advanced study in a professional field such as medicine or law; for graduate study in an area in which MIT gives no undergraduate degree; or for advanced study in an interdepartmental field. Students may also put together a six-subject minor in a field of the humanities, arts, or social sciences, which will be designated along with the major field on the S.B. diploma.

For most students, the program for the S.B. normally requires four years of full-time study. To complete work for a bachelor's degree in any Course, each student must fulfill the General Institute Requirements and must complete the departmental program specified by that Course. Details on General Institute Requirements and on selecting a major Course of study are discussed later in this chapter.

During the first year at MIT, most students take a program that includes subjects in mathematics, physics, chemistry, and the humanities, arts, and social sciences. In order to enable first-year students to study in ways that best suit their preparation and learning styles, there is a variety of ways to complete the core subjects, as well as prepare for further undergraduate study. Students may choose from a range of specified subjects or may enroll in one of the distinctive freshman programs called Concourse, the Integrated Studies Program, and the Experimental Study Group, which are described later in this chapter.

In order to begin to fulfill the Institute degree requirements (listed later in this chapter), those freshmen following the more traditional subject-by-subject format may choose one of four sequences in mathematics; one of two subjects in the chemistry area; one of two sequences in physics; and from a designated list of subjects in the humanities, arts, and social sciences. Students have five options from which to choose to satisfy the first phase of the Writing Requirement.

A possible program for the first year includes two terms of physics, two terms of calculus, subjects in the humanities, arts, or social sciences, one term of chemistry, plus one or more elective subjects, often including an undergraduate seminar or a Freshman Advisor Seminar (where the faculty leader of the seminar is also the student's freshman advisor). Many mathematics and physics sections are "linked"; students attend recitations in both subjects with the same group of students and/or are assigned to a physics section according to enrollment in a calculus subject. All subjects taken by freshmen are graded on a pass/no record basis. Some freshmen also elect to become involved in the Undergraduate Research Opportunities Program (UROP), described later in this chapter. Entering students with degree credit for one or more of the first-year subjects may substitute more advanced subjects or may use the time made available for electives or Science Distribution subjects. The procedures by which degree credit at entrance is earned are described under Admissions in this chapter.

The Concourse Program, the Integrated Studies Program, and the Experimental Study Group, which offer alternatives to the more traditional lecture/recitation, subject-by-subject format, have their own faculty, meeting places, and methods of operation. In these programs, students make progress comparable to that of

1
The various undergraduate Courses are described in Chapter VII. At the Institute, the capitalized word **Course** refers to an organized curriculum leading to a specified degree. The lowercased word **course** or **subject,** on the other hand, refers to the individual classes. Each Course is designated by a Roman numeral; individual subjects are given Arabic numerals to correspond with the Course numbers. For example, Course II and Course II-B are curricula in Mechanical Engineering; 2.05 indicates a subject given in Mechanical Engineering. The Department of Mechanical Engineering as a whole is also referred to as Course 2 or Course II.

other freshmen, but the manner in which individual Institute degree requirements are met varies both between the programs and among students within each program. In all three programs there is an especially high level of student-faculty interaction.

Concourse Program

A student who chooses the Concourse Program becomes a member of a group of about 60 freshmen working with a team of five to seven faculty members in a year-long program of study that deals with interactions of ideas and methods from engineering, science, and humanities. Concourse has operated as an alternative program for freshmen since 1971, and has been made a regular part of the MIT curriculum. A main goal of the Program is to explore both the unity and conflict of humanistic and technical viewpoints and ideas. The general approach is not only to achieve competence in the separate disciplines but to examine the mutual relevance of freshman calculus, physics, chemistry, biology, and humanities. The approach is that of a scholarly community, with intense participation and support by faculty, staff, student assistants, and freshmen.

The Concourse faculty members, representing different professional disciplines, collaborate closely in the planning and teaching of the curriculum, which fully treats the subject matter of Institute Requirements while branching out into related topics. Regularly scheduled class sessions are supplemented by various kinds of less formal activities. A student may carry at least one subject per term outside the Concourse Program. Subject matter of the Program is arranged so that the student receives credit for all of the first-year General Institute Requirements upon successful completion of the program. The structure of Concourse promotes close and sustained contact between students and faculty, and provides a coherent and balanced approach to the diversity of disciplines and research activities at the Institute.

The program supervisor for 1988-89 is Professor Robert M. Rose. A detailed description of the Program may be found in the *Freshman Handbook* or may be obtained by writing to Concourse, Room 20C-224, MIT, Cambridge, Massachusetts 02139.

Integrated Studies Program

The Integrated Studies Program (ISP) offers freshmen an opportunity to fulfill their first year requirements in a new way. The group will be limited to 40 freshmen.

ISP is designed for students interested in learning how science and engineering are done, and how those pursuits relate to the world in which they are practiced. It especially seeks students who, in addition to wanting to develop a dual competence in science/engineering and humanistic studies, are interested in hands-on experience as a mode of learning.

The goals of ISP are manifold: 1) to illustrate the connections among the sciences and engineering; 2) to highlight the cultural embeddedness of science and technology; 3) to involve students physically as well as mentally with processes of science and technology; and 4) to have students "feel" how physical materials behave when they manipulate them. We promote these activities in a context of close interaction among the Program's students, staff and faculty, and by including as many interesting visitors as possible.

For the General Institute Requirements in math, physics, and chemistry, ISP students attend the regular Institute lectures in these subjects, but have their recitations (small classes that augment the lectures) in ISP. The recitations are designed to link these subjects so that related concepts in different disciplines are illustrated and clarified. Undergraduate tutors are also available in ISP for those wanting additional help with their work.

The humanities component of the freshman year is a two semester subject in which students have hands-on experience in workshops with a number of technologies (e.g. cooking, weaving, blacksmithing, clock making, engine building, computer design) and discuss, read, and write, about the nature of those technologies and how they fit into the various cultures that "invented" and practiced them. Beyond developing a real feeling for the physical and chemical constraints of materials (which will be connected to the science core subjects), students will come to see how different cultures treat materials in their own special ways: Cultures have "technological styles" just like art styles.

Discussions of the issues raised by this doing and studying of different technologies will help to integrate the students' freshman learning experience. The mix of this range of experience and of opportunities — coursework, workshops, discussion, easy access to staff, tutors, and faculty, a "home base" in the ISP lounge and workshops — provides a setting in which students can learn about themselves, about a wide range of disciplines, and about different styles of learning, in a congenial atmosphere of mutual support and intellectual inquisitiveness.

A detailed description can be obtained from the Integrated Studies Program, MIT, 20C-117, Cambridge, Massachusetts 02139.

ESG (Experimental Study Group)

ESG is a small academic community at MIT that offers an individualized program in the core subjects for freshmen and sophomores. Students enrolling in ESG can study a variety of subjects in mathematics, physics, chemistry, humanities, social science, and computer science through a combination of tutorials, seminars, small recitation sections, study groups, and independent study projects. In contrast to the set structure of the regular curriculum, ESG's flexibility allows students to go at their own pace whenever possible, and to organize their schedules as they wish.

ESG's small classes also allow students to interact more often with faculty and fellow students than is typical in larger classes in the regular curriculum. Depending on the nature of the course material, students may choose their own topics of concentration to suit their academic interests. Although ESG can be a full-time activity for freshmen, students usually take one or two courses in the regular curriculum that are not offered in ESG.

In addition to offering a comprehensive academic program for freshmen and sophomores, ESG also provides a place where students and staff can study and socialize together. Each year, approximately 45 freshmen, 20 sophomores, 10 staff members, and 20 upperclass tutors (who have been in ESG as freshmen) participate in ESG. Staff members are drawn from MIT's Departments of Mathematics, Chemistry, Physics, and from the Schools of Engineering, and Humanities and Social Science. Interaction among community members is facilitated not only through seminars, study groups, and tutorials, but also through community activities such as weekly luncheons and weekend trips.

More information may be found in the *Freshman Handbook*, or by writing to ESG, Room 24-612, MIT, Cambridge, Massachusetts 02139.

Selection of Major Course of Study

Freshman Handbook

The preceding brief overview of the first-year academic program is meant to convey the nature and scope of the options available, but it is hardly a sufficient basis for the individual freshman to plan his or her year. Shortly after they are admitted to MIT, freshmen receive the *Freshman Handbook*, a compendium of detailed information on academics, athletics, extracurricular activities, the advisory system, and an outline of Residence/Orientation Week. Freshmen also receive the *Undergraduate Residence* book, which describes housing options. The *Handbook*, also distributed to freshman advisors, is a primary reference document for the first year.

Freshman Grading

Freshmen receive formal grades of either pass or fail in all subjects they take; failing grades in the freshman year do not appear on the permanent record. Pass/no record grading for freshmen is designed to meet a variety of objectives; among them are a reduction of the stresses of the first year (anxiety about time, class rank, the failure to do A work) and the development of more mature attitudes about learning and about managing one's time. Three times during the first year, freshmen and their instructors, in turn, are asked to complete written evaluations of the student's work. This process usually provides the student with a more comprehensive and useful evaluation than A-F grades alone.

Credit Limit for Freshmen

A freshman may register and receive credit for subjects totaling a maximum of 60 credit units in the fall term and 63 credit units in the spring term. Petitions for individual exceptions can be submitted to the Committee on Academic Performance. However, the Committee enforces the credit limit rigidly and only allows exceptions on purely technical grounds. Credit earned for passing an Advanced Standing Examination will be counted toward this credit limit unless such an exam is taken either in the September or February examination period. In view of the requirement that ROTC students take one ROTC subject each term, all AS-, MS-, and NS-numbered subjects are excluded from this credit limit.

Many entering students have a preference for a specific field, while others have interests in several areas and have not yet decided on a field of concentration. A substantial percentage of those who do enter with a decided preference, however, later find other areas more to their liking; therefore, students should be prepared to examine with an open mind the wide range of Courses available at the Institute. Students are encouraged to attend departmental orientation programs to seek out and talk with faculty and others who have experience in fields of potential interest. They are also urged to select electives that will help them think about possible majors. For many, this consideration of fields will reinforce existing convictions, while for others it will open up new avenues of interest. MIT may, however, limit enrollment in particular fields of study to balance resources with student interest.

All undergraduate degree programs combine the study of basic principles with the study of their practical applications. This combination, studied in depth, helps to foster motivation for the lifelong learning necessary for professional competence.

Students usually choose a Course at the end of the first year, though they need not do so until the end of their second year. There is sufficient overlap and flexibility so that a change in Course can be made with relative ease in the second year. Thus, even though a student may have doubts about which of two Courses to choose, he or she usually finds it wise to enroll in one of them for a year to get the true flavor of being an undergraduate in that department.

All undergraduate and graduate academic programs, as well as faculty listings, for each of the Institute's departments are described fully in Chapter VII, entitled Departmental Degree Programs and Requirements.

Each student entering MIT is assigned an advisor who assists the student in designing an effective program of study appropriate to individual interests and aspirations. For instance, the selection of elective subjects is an important consideration, one that students should discuss in depth with their advisor.

Detailed information on undergraduate registration may be found in Chapter V, Academic Procedures and Institute Regulations.

Context Subjects

Science and technology provide a powerful means by which we might achieve a more humane society — a society free of hunger, illness, illiteracy, and misery. However, the relationship between science and society is by no means unidirectional. The development of science and technology is both influenced and constrained by political and social forces which may fall outside the domain of technocratic expertise.

Consequently, all students should have the opportunity to consider critical questions about the interplay between science and technology and the social, cultural, environmental, and economic contexts in which new scientific knowledge and technological applications are pursued. To that end, experimental academic experiences about the Human Contexts of Science and Technology — Contexts Subjects — are being developed by teams of faculty members from widely different disciplines. During an initial period of experimentation and refinement of the Context idea, formal subjects will be available for students to take for ***unrestricted elective*** credit only.

The Committee on the Undergraduate Program has endorsed the Context experiment and intends that these experiences should address one or more of the following objectives:

1) to help students become more conscious of the significant commonalities that link the study of science and engineering with other branches of knowledge;

2) to increase understanding of nonscientific and nontechnological components of work in science and engineering. This objective may be accomplished by stressing the political, economic, and managerial considerations integral to scientific and technological projects, or the social consequences of certain directions of scientific research;

3) to encourage students to be more reflective about the social implications of individual actions and to motivate discussion of other personal issues, such as balancing the demands of family and career and avoiding intellectual "burnout."

These objectives will provide students with a variety of insights, including a better understanding of the generative processes of science and engineering: How do scientists and engineers go about doing what they do? How do they reason, solve problems, design their research programs, and communicate with their colleagues? Do they work differently from each other, and from artists and humanists?

Context Subjects are designed and taught jointly by faculty from different Schools. The current offerings are listed below; consult the individual catalogue listing for complete descriptions.

Further information on Contexts may be obtained from Dean Margaret Richardson in the Undergraduate Education Office, Room 20B-141, (617) 253-7909.

Context Subjects

2.93J 8.206J STS012J	Engineers, Scientists and Public Controversies (3-0-9)
2.94J 14.15J	Accounting for the Social Consequences of Technological Change (2-0-7)
3.08J 21.464J	Industrial Competition in the US and Asia (3-0-6)
6.903J STS013J	Automation, Robotics, and Unemployment (3-0-9)
7.00J 15.60J	AIDS: Scientific Challenge and Human Challenge (3-0-3)
8.202J STS014J	Life and Institutions of Science (3-0-9)
8.204J 21.441J	Does Technology Drive Politics?: The Decision to Build the H-Bomb (3-0-6)
11.017J 21.612J	Learning to Design and Designs for Learning (3-6-3)
13.95J 15.600	Negotiation in Engineering Systems (3-3-6)

The Minor in HASS

Starting in the fall term of 1988, undergraduates may elect to minor in a designated area of the Humanities, Arts, and Social Sciences (HASS). Students electing a Minor Program will study a field in greater depth than the HASS Concentration component of the Institute Requirement allows and will encounter the structure of an intellectual discipline to a greater degree; they will not only gain acquaintance with a HASS field of study but will also begin to acquire mature competence in its practice. Students who successfully complete a Minor Program will have their achievement specified by field of study on their undergraduate degree.

The Minor Programs require students to complete six subjects in a given field from a curriculum arranged into at least three levels (tiers), expressing different degrees of sophistication in the articulation and resolution of intellectual problems. Of the six subjects required for the Minor, at most five shall count toward satisfaction of the eight-subject Institute HASS Requirement, and of these five, at most one shall count toward the satisfaction of the HASS-Distribution Requirement.

The following guidelines for the Minor in HASS have been established:

1. Students may take only one HASS minor per major, and minors can only be awarded at the same time students receive the degree in their undergraduate major.

2. Students who major in a Humanities, Arts, or Social Science field may not elect a HASS MInor in the same field.

3. The HASS Minor may not be taken in the same field as the Humanities component of the Course 21E and 21S major.

4. The junior-senior pass/fail option may not be used to fulfill a minor program in HASS.

5. It is recommended that students apply for a HASS Minor Program before the third year, but no later than at least two full terms before the student would normally receive the S.B. degree. In order to apply for the HASS Minor Program, the student must consult the appropriate HASS Minor advisor

Minor Programs have been approved in the following fields:

Anthropology/ Archaeology
Economics
Foreign Languages
French
German
Russian
Spanish
History
Literature
Music
Political Science
Philosophy
Psychology
Science, Technology, and Society
Women's Studies
Writing

Detailed information on all Minor Programs may be found in Chapter VII of this catalogue and at the Humanities, Arts, and Social Sciences Information Office (14N-408) administered by the Office of the Dean, School of Humanities and Social Science.



Advanced Standing Examinations

To qualify for an Advanced Standing Examination, a student must never have been registered for or attended class in the subject concerned. A freshman who takes such an exam shall receive the grade of P for passing performance, but no record will be kept of failing performance. For all other students, a grade ranging from A to F as usual will be recorded on the transcript. Any passing grade entitles a student to full credit for the subject. For freshmen, such credit will count toward the 60- or 63-unit credit limit unless the exam is taken either in the September or February examination period (see Credit Limit for Freshmen).

Electives

Any subject offered by the Institute is open to first-year students, provided they satisfy the prerequisites. There are several hundred subjects without prerequisites from which a student may select during the freshman year.

Electives can be used for several different purposes. For example, many students who are undecided about their eventual program of study will use some part of their elective time to get more information about the various departments or fields they are considering. Other students who are more certain of their professional goals will use elective time to explore areas of secondary interest. Still others will choose to begin work on departmental or Institute requirements, deferring subjects of a more supplemental nature until a later year. For students who would appreciate insights into the social, historical, cultural, environmental and/or economic aspects in which new scientific and technological applications are pursued, enrollment in a "context" subject may be appropriate. The study of a language also may be started or continued. Freshmen should select electives that best suit their individual needs.

Undergraduate Seminars and Freshman Advisor Seminars

The Undergraduate Seminar Program offers students an opportunity to interact closely with faculty members on topics of current interest.

The Freshman Advisor Seminars also have proven particularly effective in achieving this kind of close interaction. In these seminars, the seminar leader is also the freshman advisor for the approximately eight seminar participants. Seminars vary tremendously both in style and topic. Some are oriented around small group discussions; others have speakers, go on field trips, or engage in "hands-on" research. Many topics are interdisciplinary in nature.

Most seminars carry six units of pass/fail credit, and the class size is generally restricted to a small group. Titles and descriptions of seminars to be offered in the upcoming term are published in the *Freshman Advisor Seminar* and *Undergraduate Seminar Program* booklets, published twice yearly. Copies of the current booklets are available in the Undergraduate Academic Support Office, Room 7-104.

Junior-Senior Pass/Fail Option

A student may opt to take a total of two subjects on a pass/fail basis during his or her junior and senior years. This option is intended to provide students with an opportunity to broaden their education by taking subjects that may not be in their area of expertise without concern for its effect on their academic record. It is therefore expected that this option will be designated at the time the student initially registers for the subject, but the deadline for this decision is add date. Such subjects may not be used to fulfill either an Institute or a departmental requirement.

Program for Two Bachelor's Degrees

A student may work for two Bachelor's degrees to be received separately or concurrently. He or she must submit to the Registrar (at least two full terms before the student would normally receive the second of the two S.B. degrees) a petition that indicates the desire to work for two degrees. The petition must have been approved by faculty advisors in each of the two departments concerned. The requirements of each department must be satisfied and the combined program must contain at least 90 units in addition to the requirements for one of the degrees. Both faculty advisors should take responsibility for examining the entire program in the same way as they would for a candidate for a single S.B. degree. Students should consult the Student Financial Aid Office regarding any impact this arrangement might have on eligibility for MIT or Federal financial aid.

Information about the simultaneous award of two masters' degrees and the simultaneous award of a bachelor's and master's degree may be found in Chapter IV of this catalogue.

Undergraduate Research Opportunities Program (UROP)

UROP invites undergraduates to participate with MIT faculty and staff members in a wide range of research activities in every academic department and most interdisciplinary laboratories.

There are many advantages to becoming involved in such pursuits as early as possible in an undergraduate career: establishing ties to faculty; having access to the advising, counseling, and tutoring resources of a professional group; trying out a potential major; acquiring data-gathering and laboratory techniques; exploring the frontiers of a field; undertaking topics not amenable to the classroom; facing a real-world problem; and establishing a focus for educational experiences. Through UROP, students can come to have a better understanding of the intellectual process of inquiry, while experiencing an opportunity for personal and professional growth.

Ground rules for participating in UROP are contained in the *UROP Directory*. Coordinators for Institute departments, laboratories, and offices are listed under each *Directory* entry. These people are prepared to assist students, but a certain amount of footwork and negotiation will be required in order to achieve a satisfying collaboration. The UROP experience will be unlike any other; its benefits and rewards are great, but expectations and standards are commensurately demanding. Call or visit the UROP section of the Undergraduate Education Office, Room 20B-141, (617) 253-7909 at any time, for advice and assistance.



Women's Studies

The **Women's Studies Program** at MIT offers students an opportunity to gain a new and exciting perspective on existing disciplines. The Program seeks to include women and gender as categories of analysis in all traditional scholarly inquiry. Though the conditions and quality of women's lives have differed from those of men in most cultures and periods of history, academic research and course content often fail to consider the role of gender in social systems. The primary objective of the Women's Studies Program is to encourage the reexamination and reinterpretation of existing data, and to promote the discovery of new knowledge about women and gender.

The Women's Studies Program provides students a unique opportunity for interdisciplinary study through various subjects offered at MIT. The core subject, Introduction to Women's Studies, asks students to challenge traditional assumptions and questions in a variety of disciplines, including literature, history, psychology, philosophy, anthropology, and biology.

The faculty members involved in the Women's Studies Program are drawn from all areas of the Institute and offer subjects in the fields of biology; art and architecture; psychology; literature; history; anthropology; and science, technology, and society. There also are opportunities to pursue gender-related topics in other academic departments at MIT, and through the Experimental Study Group (ESG). Women's Studies offers distribution subjects as well as a field of concentration and a minor. Subjects are listed in the SP section of Chapter VIII in this catalogue. Degree programs in Women's Studies are available by petition.

The **Women's Studies Research Room,** housed next to the Program's offices in the Humanities Library, offers faculty and students a central location for the study of women and gender. It contains a core library of relevant materials, including books and journals. The Women's Studies Program also functions as an information clearinghouse for all students interested in Women's Studies classes at MIT, Wellesley, or Harvard. A wide range of announcements and information relevant to feminist scholars in the Boston area and others interested in Women's Studies is posted on the bulletin board.

Further information about the Women's Studies Program may be obtained by contacting Professor Isabelle de Courtivron, Director, or Barbara Schulman Women's Studies Program, Room 14E-316, MIT, Cambridge, Massachusetts 02139, (617) 253-8844.

Preprofessional Advising and Education

Within the Office of Career Services (Room 12-170), the Preprofessional Advising programs serve students who are interested in pursuing professional postgraduate education, particularly in the fields of medicine, law, and psychology. The staff in the Office works closely with both the Premedical Advisory Council and the Prelaw Advisory Council.

Premedical Education

Each year, between eight and ten percent of the senior class, as well as a large number of alumni and graduate students, go on to medical study. Students in nearly every Course of study are represented among the applicants. At MIT, students have great flexibility in their choice of major fields, and are encouraged to take advantage of the diversity of subjects offered at the Institute. Students major in their chosen course of study and complete medical school entrance requirements through a selection of electives; such programs fully meet the specifications of the Association of American Medical Colleges. MIT applicants continue to excel in their admissions rates to medical schools.

The Premedical Advisory Council, whose members are directly involved in medical practice, medical research, or student counseling, provides guidance and information to students interested in medical careers. The Office of Career Services and Preprofessional Advising, Rooms 12-170 and 12-185, (617) 253-4737, maintains Medical College Admissions Test application forms, school catalogues, *A Pre-Medical Handbook for MIT Students,* and other information pertinent to medical study. Students interested in medicine are encouraged to make an appointment by at least the second term of their sophomore year. Students interested in medicine are assigned to a premedical advisor at that time.

Prelaw Education

A number of MIT students enter law school each year. Law schools do not require a particular undergraduate program as a condition for admission; students from every Institute School have been admitted to law school. Prelaw students should consult members of the Prelaw Advisory Council regarding preparation for a legal education and make contact with the Preprofessional Office at least during their junior or senior year.

The Preprofessional Advising Office maintains the catalogues of accredited law schools, the dates and application materials for the Law School Admissions Test, and other information pertinent to the study of law. *A Handbook for MIT Students Interested in Law* has been prepared to answer questions commonly asked by students interested in a legal education. Copies of this and other helpful publications are available in the Office of Career Services and Preprofessional Advising. Please see the section on Law-Related Studies in Chapter VI of this catalogue for a further discussion of opportunities and programs in this area.

Education Studies

MIT students may receive certification to teach in the Commonwealth of Massachusetts by taking a prescribed series of subjects through the MIT-Wellesley Exchange Program. (MIT Room 7-108, (617) 253-1668). Subjects in political science, psychology, humanities, and management deal with specific educational problems. Students are encouraged to consult the faculty in the Education Department at Wellesley to plan their programs as early as possible.

ROTC Programs

Air Force ROTC Program

Military training has existed at MIT ever since the Institute opened its doors. More than 12,000 officers have been commissioned from MIT, of which more than 150 have reached the rank of general or admiral. Three branches of the military operate Reserve Officer Training Corps Programs at MIT: the Army, Navy/Marine, and Air Force. Although eligibility requirements may differ slightly between the three services, described later in this section, the following conditions are common to all programs:

1. Application to any ROTC program is voluntary.
2. Admission to ROTC programs at MIT is selective.
3. All three programs admit men and women.
4. Generally, it is desirable that students enter a ROTC program at the beginning of their freshman year. However, entry during the second semester of the freshman year, either semsester during the sophomore year, or at the beginning of the junior year is available through special programs.
5. Students must complete the ROTC program, including summer training, and earn their Bachelor's degree in order to be eligible for a commission.
6. All students may compete for scholarships, which commence at the start of either the freshman, sophomore, or junior year.
7. Enrollment as a scholarship recipient beyond the freshman year generally creates an obligation for four years of active service or, in some cases, for alternative service involving reserve duty.
8. Enrollment as a nonscholarship freshman or sophomore in any program does not incur a military service obligation.
9. Participants must agree by contract to maintain levels of aptitude and academic performance established by the three programs. Participants also contract to remain physically qualified. Breach or willful evasion of this scholarship contract could lead to a period of enlisted service or to repayment of scholarship funds.

Specific information concerning benefits, ROTC training programs, career opportunities, and contractual obligations can be obtained from the program offices listed in this section.

The Air Force ROTC program provides students the opportunity to become Air Force commissioned officers while completing their undergraduate or graduate degree. It is designed to develop the leadership and management skills essential for an Air Force officer while preparing the student for assignment in a career field related to his or her academic specialty. The Office of Aerospace Studies offers two programs — one of four years and one of two years — for students to qualify for commissions.

The Four-Year Program

The four-year program consists of classroom and leadership laboratory work during the four undergraduate years and one summer training period of four weeks between the sophomore and junior years at a United States Air Force Base. It is possible for students with three academic years remaining to enroll in the four-year program by combining the first two years.

The first two years of the four-year program are known as the General Military Course (GMC). Upon completion of the GMC and summer field training, students may compete for entry into the Professional Officer Course (POC). Selection into the POC is based on academic aptitude and performance, successful completion of the GMC and field training, and recommendation of the Professor of Aerospace Studies. All cadets in the POC receive a $100 nontaxable allowance each month.

Students desiring to pursue an advanced degree may apply for delayed entry to active duty. Advanced degree programs are also available through the Air Force Institute of Technology for selected officers.

The Two-Year Program

The two-year program is for those students who do not complete the first two years of the four-year Air Force ROTC program. Such students may apply as undergraduates (during their sophomore or subsequent years) or graduates if they have two years remaining in their academic program at MIT. In lieu of completing the GMC, these students receive six weeks of field training at an Air Force base during the summer preceding their entry into Air Force ROTC. They receive the same benefits and complete the same academic program required of POC members in the four-year program. Students applying for the two-year program may also compete for scholarships.

Scholarships

Air Force ROTC scholarships are available on a competitive basis to qualified applicants in selected academic majors. Each scholarship pays tuition and required fees. Scholarship recipients also receive an allowance for textbooks and a $100 nontaxable allowance each month during the academic year. Scholarships for 3 1/2, 3, 2 1/2, and 2 years are available in addition to the four-year scholarships offered to high school seniors.

Program of Instruction

First year (6 units): AS 11, AS 111, AS 12, and AS 121. Second year (6 units): AS 21, AS 211, AS 22, and AS 221. Third year (14 units): AS 31, AS 311, AS 32, and AS 321. Fourth year (14 units): AS 41, AS 411, AS 42, and AS 421. These courses are described in Chapter VIII. The Aerospace Studies curriculum emphasizes the history, organization, and mission of the Air Force, including its role in national defense strategy and American society. Academic classes and leadership laboratory activities provide training and practical experience in developing leadership and managerial skills. Scholarship cadets must also fulfill English composition and foreign language requirements.

Eligibility Requirements

To be eligible for the Air Force ROTC scholarship program and the POC, students must be: 1) citizens of the United States; 2) physically qualified in accordance with existing Air Force regulations; and 3) enrolled at MIT, Harvard, Tufts, or Wellesley as a full-time student.

Application Procedure

Eligible freshmen can sign up for the AFROTC Program by registering for Aerospace Studies courses (AS 11 and AS 111). AFROTC scholarship freshmen must contact the AFROTC office as soon as they have been notified of admission to the Institute. Other interested students can apply by a personal visit to the Office of Aerospace Studies, Room 20E-111, MIT, Cambridge, Massachusetts 02139, or by calling (617) 253-3755. The director of the program is Colonel Gary G. Nelson, Visiting Professor of Aerospace Studies.

Army ROTC Program

All students at MIT, Harvard, Tufts, and Wellesley College are eligible to enroll in the Army Reserve Officer Training Corps Program hosted at MIT, the completion of which leads to a commission as a Second Lieutenant in the Regular Army, Army Reserve, or Army National Guard. Freshmen and sophomores normally enroll in the standard four-year program, while graduate students and selected undergraduates with two or more academic years remaining may apply for the Army ROTC two-year program. Successful completion of both academic and summer training requirements qualifies the student for commission upon graduation.

The academic portion of the Army ROTC program consists of the Program of Instruction as listed and one related subject per year, plus a 90-minute leadership laboratory each week. Although the normal pattern is for the student to progress through the Military Science programs sequentially, individual students may, on a case-by-case basis, be granted credit for part or all of the first two years for appropriate academic or military work experience. Selected subjects may be offered during the Summer Session. Elective subjects accepted for the ROTC program are derived primarily from the humanities, political science, management, and psychology areas. They are intended to instill in the potential officer a balanced appreciation of the development and dynamics of military and social institutions and their interrelationship with society, as well as an understanding of the interactions and management of individuals in groups. The purpose of this integrated approach to ROTC is to develop officers skilled not only in the pragmatics of Military Science, but in the related human and social institutions as well. The selection of approved elective subjects is not rigid, and any relevant subjects may be selected by the student and approved by the Professor of Military Science.

Students completing the ROTC program will receive commissions upon graduation and go on to serve as an active or reserve duty officer. The commitment depends upon the student's choice of commissioning program, scholarship status, and the needs of the service. Commissions are offered in all of the Army's functional branches with actual branch assignment determined by the needs of the Army, the desires of the student, and the academic background and experience of the student.

Enrollment in the first two years of the four-year program is voluntary and does not obligate the student to any type of active or reserve duty commitment. However, ROTC scholarship students continuing the program beyond the freshman year may incur an active duty or reserve duty obligation.

The summer training requirement for students in the four-year program is limited to the six-week ROTC Advanced Camp, which normally is completed between the junior and senior years. Students at the Advanced Camp are paid at the rate of half the pay of a Second Lieutenant, and are furnished food, housing, equipment, and medical care at Government expense, plus mileage to and from the camp location.

Two-, three-, and four-year scholarships are available each year, and are awarded on the basis of a national competition. In general, the scholarships cover the cost of tuition, books and supplies (a flat rate), and fees, plus a stipend of $100 per month. Nonscholarship students in the final two years of the program receive the $100 per month stipend. Details on the scholarship program may be obtained by contacting the Army ROTC Department.

In addition to the requirements outlined above, Army Airborne, Ranger, Air Assault, Aviation, Northern Warfare, and other Military schooling and training programs are available on a voluntary basis to qualified students. Full details on these programs are also available from the Army ROTC Department.

Program of Instruction

One Institute elective subject is required for each year in addition to the following. First year: MS 111 and MS 121. Second year: MS 21, MS 211, and MS 221. Third year: MS 31, MS 311, and MS 321. Fourth year: MS 41, MS 411, and MS 421. These subjects are described in Chapter VIII. The Military Science courses do not earn MIT credit; however, participation in at least two years of the ROTC program satisfies one-half of the Institute's Physical Education Requirement.

Eligibility Requirements

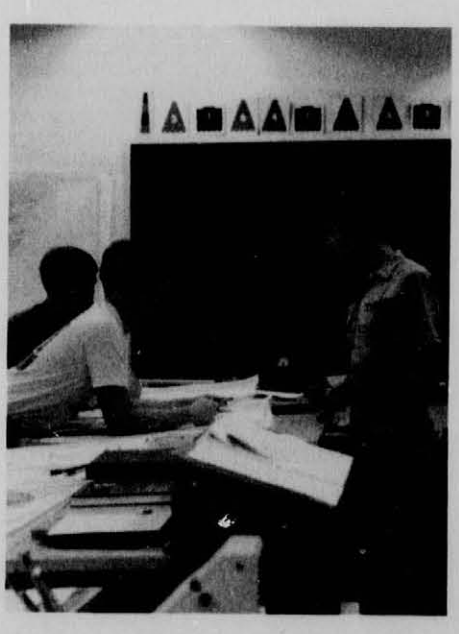
The requirement for entry into the Basic Course of the four-year program is that the student must be able to qualify for a commission before reaching his or her 30th birthday. A noncitizen may participate in and complete the first two years of the program, but must at least become a permanent resident alien in order to enroll in and complete the final two years, and receive a commission in the reserves.

Qualified applicants for the two-year program must successfully pass an aptitude test and an Army physical examination. Veterans and current members of the Army Reserve or National Guard may receive credit for the first two years of the program.

Application Procedures

Application for the four-year program normally is effected by enrollment in MS 111. Students enroll in this course during the regular registration period at MIT. The student should contact the Army ROTC Department if additional information is desired.

Students interested in the two-year program should apply through the Army ROTC Department. Further details may be obtained from Room 20E-126, MIT, Cambridge, Massachusetts 02139, (617) 253-4471. The director of the program is Lieutenant Colonel Edward D. Hammond, Corps of Engineers, Visiting Professor of Military Science.



Study at Other Universities

Naval ROTC Program

Available Programs

The purpose of the Naval ROTC program is to provide instruction and training in naval science subjects which, when coupled with the prescribed MIT engineering or science curricula, qualify selected students for commissions in one of the many specialties in the Navy. Primary officer program options available include aviation, submarines, surface warfare, and the Marine Corps.

The Naval ROTC unit at MIT offers two officer development programs. The Scholarship Program provides full tuition, certain fees, use of books and uniforms, and $100 per month for two, three, or four years. All scholarship students incur a four-, five-, or six-year active duty obligation depending on duty option. The College Program consists of four-, three-, and two-year programs. These students receive Naval Science books and all uniforms in addition to $100 per month during the last two academic years. Students in this program must complete one summer cruise after their junior year and incur a three-year active duty obligation. Each year the top College Program students receive scholarships for their remaining years in school.

Two-year Scholarship and College Program students attend the six-week Naval Science Institute at Newport, Rhode Island, in the summer before junior year. This brings their training up to the point of the four-year students before entering the advanced course. All students receive travel costs to and from this summer training, as well as the current active duty pay rate during the course.

Harvard, Wellesley College, and Tufts students are eligible for both the Scholarship and College programs.

Upon completion of the program and receipt of a baccalaureate degree, the scholarship graduate is commissioned as an Ensign in the Navy or Second Lieutenant, in the Marine Corps. College Program graduates receive commissions in the Navy or the Marine Corps Reserve. All newly commissioned officers report directly to active duty. Upon completion of the active duty obligation, the officer may be released to inactive duty, but must retain the commission for a total of eight years from the date of its original acceptance.

Program of Instruction

The NROTC program of instruction encompasses the science of nautical matters and principles of management — all vital to being a naval officer. The program has three interacting and equally important aspects. The first aspect consists of the professional academic subjects taught by the Department of Naval Science (outlined below). The second aspect consists of the academic subjects taught by the Institute. In addition to recommended coursework, one year of calculus, physics, English, American Military Affairs of National Security Policy, and one term of computer science, and an Indo-European or Asian language are required. The third aspect consists of the professional training gained from leadership laboratories (two hours a week throughout the year), tours conducted to local naval facilities, cruises aboard ship, and practical navigation and piloting practice conducted aboard training craft.

Students entering as sophomores can complete the requirements for commissioning in three years by beginning with the second-year Naval Science curriculum and making up the two missed Naval Science subjects (NS 11 and NS 12).

While completing degree requirements in one of the MIT Courses, all students in the Naval ROTC program must take the following subjects prior to graduation. First year (9 units): NS 11 and NS 12. Second year (10 units): NS 21 and NS 22. Third year (14 units): NS 31 and NS 32. (NS 12, NS 21, and NS 31 are normally given in conjunction with MIT accredited seminars.) Fourth year (10 units): NS 41 and NS 42. For Marine Option students only: NS 33, or a staff-specified MIT subject such as STS 321, in lieu of NS 31; NS 34 in lieu of NS 32; and NS 43 in lieu of NS 42. These subjects are described in Chapter VIII.

Eligibility Requirements

To be eligible for the four-year Naval ROTC program, an entering student must be: 1) a citizen of the United States; 2) at least 17 years of age and not more than 27 1/2 years of age by June 30 of the year of college graduation; 3) physically qualified, and total visual acuity must meet the current standards, correctable to 20/20 by the use of lenses. If you do not meet all these criteria, but are still interested in a Navy or Marine Corps commission, there are other financial assistance programs available.

Application Procedure

Further inquiries should be addressed to the Commanding Officer, NROTC and Naval Administrative Unit, Room 20E-125, MIT, Cambridge, Massachusetts 02139, or any US Navy Recruiting Station.

Junior Year Abroad

Many opportunities are open for study in foreign countries through participation in one of the excellent programs administered by nonprofit educational organizations or through an individually arranged program. Plans for study abroad should be worked out by each student with his or her faculty advisor and the Office of Career Services and Preprofessional Advising, Room 12-170, (617) 253-4733. The Office of Career Services can provide a great deal of assistance and information as a student plans for study at another college or university. Although almost any field can be studied abroad, it is generally advisable to take most professional subjects at MIT. By emphasizing the language, literature, history, and culture of the host country, the year abroad can be a valuable learning experience.

Effective working command of the language of the host country is vital. By conscientious work in language subjects here, even a student without prior study frequently can achieve proficiency in a foreign language by the beginning of the junior year if he or she begins by the second term of the freshman year. The orientation period provided by most organized programs will be a necessary complement in many cases. For a mature student with exceptional competence in the language and some knowledge of the culture, an individual program may be desirable, but careful planning is still essential.

A student on an approved junior-year abroad program maintains, without payment of MIT tuition, official MIT registration as an "undergraduate on foreign study," and thereby student aid status and dormitory priority. Total costs including travel sometimes are less than that at the Institute.

Students who have participated in an approved one-year program may normally expect to receive one year of equivalent credit toward their MIT degree, upon successful completion of their studies and subsequent return to MIT. Students who wish to have transfer credit posted to their MIT transcripts should submit confimation of approved credit (with necessary signatures of approval) to the Registrar's Office by the end of the 11th week (drop date) of the term they return to MIT.

Domestic Year Away

This program provides the opportunity to spend from one semester to one year at another academic institution for the pursuit of work generally not available at MIT. A student on such an approved program maintains, without payment of MIT tuition, official MIT registration as an "undergraduate studying away," with student aid status and dormitory priority. Approval for Domestic Year Away status requires that:

1
the student show that the objectives of the planned program of study are consistent with his or her overall degree program at MIT and that he or she has the academic and personal qualifications that will ensure maximum benefits from the experience;

2
the student demonstrate that the planned program of study draws on resources available at the second institution that are not generally available at MIT or at the institutions with which MIT has cross-registration privileges; and

3
the student be accepted by a school of established academic merit for a program involving a work load comparable to that at MIT.

Students who wish to have transfer credit posted to their MIT transcripts should submit confirmation of approved credit (with necessary signatures of approval) to the Registrar's Office by the end of the 11th week (drop date) of the term they return to MIT.

Those students interested in these programs should consult the Office of Career Services, Room 12-170, (617) 253-4733.

Harvard University

A limited number of MIT undergraduates is permitted to take one or two subjects at Harvard University (Faculty of Arts and Sciences) for degree credit at no extra charge, provided the subjects are not offered regularly at MIT. Cross-registration is normally limited to upperclassmen who must be regularly enrolled at MIT and paying full tuition for the term in question. No more than two regular subjects nor more than one intensive subject may be taken at Harvard in any one term. Arrangements are made through the Humanities, Arts, and Social Sciences Office. Letter grades earned in Harvard subjects appear on the transcripts of MIT undergraduates.

Wellesley-MIT Exchange Program

Participation in the Wellesley-MIT Exchange Program can expand the educational opportunities for students of each institution. Under this program, students may cross-register for any courses at the other school, with the only requirement being that they present the necessary prerequisites. MIT students may use Wellesley courses to meet certain Institute requirements, as described later in the section.

A small, liberal arts college for women located on a 500-acre woodland campus 20 miles west of Boston, Wellesley College provides a different yet no less challenging environment for learning and living from that of MIT.

Wellesley and MIT operate free weekday bus service between the two campuses for students who are cross-registered. The ride is about 50 minutes each way, so students should plan for at least one hour between their Wellesley and MIT classes. Cross-registered students have priority in boarding, but others with MIT or Wellesley identification cards may use the bus on a space-available basis.

MIT students register for a Wellesley course simply by putting the course name and number on their MIT registration form or correction form in the space marked "Cross Registration at Wellesley." Students must also register at Wellesley during the first week of classes.

Wellesley subjects and grades are recorded on students' MIT transcripts. Unless otherwise stated in the Wellesley *Bulletin*, a semester course receives one Wellesley unit of credit, which equals 12 (3-0-9) MIT units (or the equivalent of one subject when used to satisfy the General Institute Requirements).

MIT students receive letter grades for their Wellesley courses unless 1) the course is designated mandatory "credit/noncredit" by Wellesley, 2) they are freshmen under MIT's "pass/no record" requirement, or 3) they are juniors or seniors using one of their two MIT electives for pass/fail. Under Wellesley's credit/noncredit system, credit is awarded for C-level work or above.

Students may take Wellesley courses to meet a variety of MIT distribution and concentration requirements. There are, however, some restrictions and special procedures, which are described as follows.

Students generally cannot substitute Wellesley courses for MIT Science Core courses (Chemistry, Physics, and Calculus) or Laboratory Requirement courses. They may take Wellesley courses to satisfy Science Distribution Requirements, but need the approval of the Committee on Curricula.

To meet the Distribution portion of the MIT Humanities, Arts, and Social Sciences Requirement, students may take the Wellesley courses listed under the various fields in the HASS Distribution section in this chapter. Wellesley courses may be designated as part of the Concentration in the Humanities, Arts, and Social Sciences at the discretion of the designated advisor in that field of concentration. Students may use Wellesley courses as unrestricted electives toward fulfilling the Humanities, Arts, and Social Sciences Requirement, but they must petition to do so. Petitions may be obtained from the Exchange Office at MIT or from Ikey Spear in the Humanities, Arts, and Social Sciences Office, 14N-409, (617) 253-4443 (who can also answer questions pertaining to the Humanities, Arts, and Social Sciences Requirement).

Wellesley subjects may be used to fulfill departmental requirements with the permission of a faculty advisor.

General Institute Requirements

Most examinations at Wellesley are offered on a self-scheduled basis. Wellesley's academic calendar differs from MIT's. Students are responsible for meeting Wellesley's end-of-term deadlines. Students may obtain information on end-of-term procedures from the Exchange Office at MIT.

Students unable to complete their work due to grave emergency or illness should contact the Exchange Coordinator at Wellesley within 24 hours of the deadline to get further instructions.

Students may take physical education classes at Wellesley on a space-available basis and may apply these classes toward their MIT physical education requirements.

MIT students receive full library privileges at the Wellesley College Library.

The following areas of study are available at Wellesley:

American Studies
Anthropology
Architecture
Art
Astronomy
Biological Sciences
Black Studies
Chemistry
Chinese
Classical Civilization
Cognitive Science
Computer Science
Economics
Education
English
French
Geology
German
Greek and Latin
History
Italian
Japanese
Jewish Studies
Language Studies
Mathematics
Medieval/Renaissance Studies
Music
Peace Studies
Philosophy
Physics
Political Science
Psychology
Religion
Russian
Sociology
Spanish
Technology Studies
Theatre Studies
Women's Studies

Complete details on registration procedures and programs, as well as copies of the Wellesley *Bulletin* and class schedules, are available in the Exchange Office at MIT in Room 7-103, (617) 253-1668. The Exchange Office at Wellesley is located in Room 340B, Green Hall, 235-0320 x2321 (through the MIT tie line: 187-2321).

To be recommended for the degree of Bachelor of Science, students must have attended the Institute not less than three regular academic terms (two terms for Classes entering prior to September 1986), which ordinarily must include the term of graduation. Also students must have satisfactorily completed programs of study approved in accordance with the faculty regulations, including the General Institute Requirements described on the following pages, and the Departmental Program of the Course in which the degree is to be awarded. A student must petition the Committee on Curricula for any substitutions in the General Institute Requirements. Departures from the Departmental Programs are allowed with departmental permission. The Departmental Program and the total degree requirements are shown for most Courses in Chapter VII.

Some changes have been made recently in the Bachelor of Science degree requirements; **the following information is applicable to the Class entering MIT in September 1986 and subsequent Classes:**[1]

General Institute Requirements	
Science Requirement Chemistry (3.091 or 5.11) Physics (8.01 or 8.012 and 8.02 or 8.021 or 8.022) Calculus (18.01 or 18.011 or 18.012 or 18.013 and 18.02 or 18.021 or 18.022 or 18.023)	5 subjects
Humanities, Arts, and Social Sciences Requirement	8 subjects
Science Distribution Requirement	3 subjects
Laboratory Requirement (12 Units)	1 subject
Total	**17 Subjects**
Writing Requirement To be satisfied in two stages	
Physical Education Requirement	
PLUS	
Departmental Program and Unrestricted Electives As specified for each Course, **180-198 units** in addition to the General Institute Requirements.[2]	

Until an audit of these new requirements can be provided on grade reports, students can keep track of their progress by checking off the subjects that count toward the 17-subject General Institute Requirements (noting the restrictions on the Science Distribution Requirement); the remaining units then count toward the additional 180-198 units for departmental programs and elective credit.

1
The degree requirements for Classes entering MIT prior to September 1986 are shown in the Departmental Degree Programs Chapter (Chapter VII). Transfer students generally will graduate under the requirements that apply to the Class they join when they enter MIT.

2
Departmental Programs can specify or expect up to three subjects from the General Institute Requirements, and must make possible at least 48 units in unrestricted electives (usually more). The total of 180-198 units does not include ROTC subjects, if elected.

Science Requirement

MIT expects its graduates to have an understanding and appreciation of the basic concepts and methods of the physical sciences. These concepts and methods are needed in most degree programs at the Institute. More importantly, they are an essential part of the background that MIT graduates bring to their roles as professionals and as broadly educated citizens in a world deeply influenced by science and technology.

To provide this understanding, the Institute offers a variety of programs by which the student can fulfill the science, laboratory, and science distribution requirements. These programs introduce the student to three basic elements of the scientific method: experimental foundations and techniques, mathematical analysis, and conceptual models for experimental facts. Important experimental, as well as conceptual, aspects are introduced by the chemistry requirement and by the laboratory requirement. Mathematical methods common to much of science and technology are explored in the calculus requirement. Basic concepts that underlie many physical phenomena are defined and elucidated in the physics and in the science distribution requirements.

In addition to a rigorous introduction to the sciences, these requirements are intended to stimulate and challenge each student to review critically his or her knowledge and to explore alternative conceptual and mathematical formulations which may provide better explanations of natural phenomena or may lead to better applications of technology.

The development of critical and constructive approaches to both theory and practice in science, engineering, and other professions is a central objective of the Institute's educational programs.

Chemistry

The requirement can be satisfied by taking either 3.091 Introduction to Solid State Chemistry or 5.11 Principles of Chemical Science. 3.091 is designed for students who are particularly interested in the chemistry of the solid state. 5.11 presents an introduction to chemistry with an emphasis on basic principles and their applications.

Physics

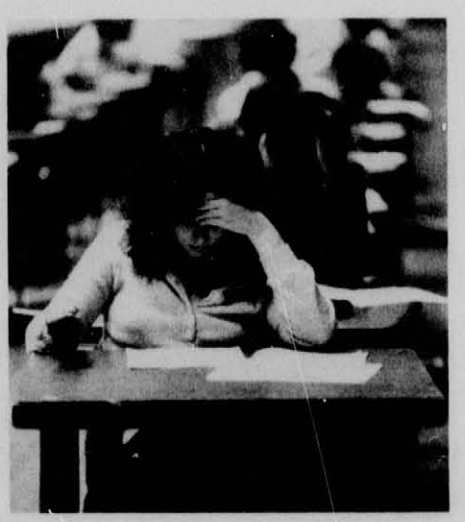
The Institute requirement in physics may be satisfied through a variety of combinations of first- and second-term physics subjects. A majority of students find the 8.01-8.02 sequence suited to their needs. 8.012-8.022 covers essentially the same subject matter as 8.01-8.02, but is more advanced mathematically; calculus is used freely from the beginning of the term. The student is not obliged, however, to follow through the whole of either of these sequences as a package, should some other choice become more suitable. It is quite acceptable to switch from a first-term subject in one sequence to a second-term subject in the other.

Calculus

The Department of Mathematics offers two standard calculus sequences: 18.01-18.02 and 18.011-18.021. These sequences seek to present calculus as it will actually be used in science and engineering. The subjects differ in several respects: content and intensity (see subject descriptions for details), structure (homework and testing practices vary), and prerequisites (18.011 assumes a year of high-school calculus). In addition, 18.01 is also offered in an alternative version, 18.01A.

A third sequence, 18.012-18.022 Calculus with Theory, assumes an extensive background in calculus, and emphasizes proofs.

Students with advanced placement or advanced standing credit for 18.01 will lose it if they take 18.01. However, for students taking 18.011 or 18.012, it will be replaced by six units of elective credit.



Writing Requirement

The primary objectives of this General Institute Requirement are: to ensure competency in writing of all undergraduates, with special emphasis on writing in professional contexts, and to see that clear, effective writing is valued and fostered throughout the curriculum as an essential part of an MIT education.

The basic features of the requirement are early evaluation, a variety of ways to complete the requirement, and Institute-wide involvement. The requirement is to be satisfied in two phases:

Phase One is concerned with the proficiency in general expository writing that should be expected of any educated person. The options for satisfying this stage are:

a) achieving, prior to entry, a score of 750 or above on the College Board Achievement Test in English Composition with Essay or a score of 5 on the College Board Advanced Placement Text in English Language and Composition.

b) passing the Freshman Essay Evaluation which is offered to new students during Residence/Orientation Week and once during the fall semester. An optional English as a Second Language (ESL) version is available.

c) receiving a grade of pass in any **one** of the following expository writing subjects: 21.334 Expository Writing II for Undergraduates: English as a Second Language, 21.730 Expository Writing, 21.731 Writing and Experience, or 21.732 Introduction to Technical Communication; or any equivalent subject in Project Interphase, the Experimental Study Group, the Integrated Studies Program, or Concourse.

d) submitting a paper of five pages (1,250 words) or more of expository prose written for any MIT subject or UROP activity and judged satisfactory by the professor of the subject and by evaluators for the requirement. Papers for any given semester will be accepted until the end of the fifth week of the following term.

Students submitting papers for Phase One must first pick up a cover sheet from the Writing Requirement Section of the Undergraduate Education Office, Room 20C-105, for the subject instructor to sign. Instructors are encouraged to use the cover sheet to comment on the student's writing before signing the sheet and giving it to the student. The student then returns the paper and the cover sheet to the Committee office.

The specific goals and context of the writing assignment should be explicitly or implicitly stated, either by the instructor on the cover sheet or by the student in the paper's introduction.

Students normally complete Phase One by the end of the freshman year and must complete this stage of the requirement by the eighth week of the first semester of their sophomore year. Students who fail to do so will be considered to be in noncompliance with the requirement and will then only be able to employ the paper option for statisfying Phase One by successfully petitioning the Committee on the Writing Requirement.

Phase Two is designed to engage upperclass students in the more specialized forms of writing that are necessary within their professional disciplines. These encounters, which go beyond the writing experiences provided by the Humanities, Arts, and Social Sciences Requirement, occur over an extended period in the middle years of students' undergraduate careers.

Phase Two is administered by individual departments. Students should contact their Departmental Advisor or Writing Coordinator for specific information on completing this part of the requirement.

Phase Two should be satisfied by the end of the junior year and must be satisfied by the end of the first semester of a student's senior year. Beginning with the Class of 1990, students who fail to complete Phase Two by registration day of the semester in which they plan to graduate will be withheld from the Degree List and will be subsequently added to the Degree List only by successfully petitioning their Departmental Writing Coordinator and the Committee on the Writing Requirement.

Options for completing this phase are:

a) receiving a grade of B or better for the quality of writing in a cooperative writing subject within the general area of a student's professional field. These cooperative engineering and science subjects include instruction and evaluation by Writing Program faculty and provide excellent opportunities for satisfying Phase Two.

b) receiving a B or better in any **one** of the following advanced subjects in scientific and engineering writing: 21.339 Workshop in Writing for Science and Engineering: English as a Second Language, 21.340 Workshop in Writing for the Social Sciences and Architecture: English as a Second Language, or 21.780 Science and Engineering Writing.

c) submitting a paper of ten pages (2,500 words) or more of prose from any MIT subject or UROP activity within the general area of a student's professional field that is judged satisfactory by the instructor or supervisor and by evaluators for the requirement. Students who wish to use this option to complete Phase Two should contact their Departmental Writing Coordinator.

The Committee on the Writing Requirement has published a brochure on the requirement. Copies are available at the Writing Requirement Section of the Undergraduate Education Office, Room 20C-105, (617) 253-7909. Students are also encouraged to discuss any questions they may have about the requirement with their Departmental Writing Coordinator or with the Institute Coordinator of the Writing Requirement, Dr. Les Perelman.

Humanities, Arts, and Social Sciences (HASS) Requirement

MIT provides a substantial and varied program in the humanities, arts, and social sciences that forms an essential part of the education of every undergraduate. This program is intended to ensure that students develop a broad understanding of human society, its traditions, and its institutions. This requirement enables students to deepen their knowledge in a variety of cultural and disciplinary areas and encourages the development of sensibilities and skills vital to an effective and satisfying life as an individual, a professional, and a member of society.

More specifically, the objectives of the program are to develop: 1) skills in communication, both oral and written; 2) knowledge of human cultures, past and present, and of the ways in which they have influenced one another; 3) awareness of concepts, ideas, and systems of thought that underlie human activities; 4) understanding of the social, political, and economic framework of different societies; and 5) sensitivity to modes of communication and self-expression in the arts. Work in these areas will, where appropriate, display a special concern with the relation of science and technology to society.

The student's program in the humanities, arts, and social sciences (HASS) is based on the following Institute requirement:

1
Every candidate for a bachelor's degree must have completed a **minimum of eight term subjects (of at least nine units each)** in the humanities, arts, and social sciences, normally at the rate of one subject each term.

2
Distribution. Three of the eight subjects must be chosen from a specially designated list of distribution subjects in the humanities arts and social sciences. The three subjects are to be selected from three separate categories or fields and may be taken at any stage of the student's undergraduate career.

3
Concentration. Before the third year, each student selects a field of concentration. The requirements for concentration are set by each field and consist of either three or four subjects. An individual's program of concentration is arranged in consultation with a designated advisor in the field. A distribution subject in a given category or field may also be counted as one of the required concentration subjects with the permission of the concentration advisor. In individual cases, a special interdisciplinary program of concentration may be arranged with the approval of an advisor designated by the Dean of Humanities and Social Science. This approval **must** be obtained ahead of time, before the desired combination of subjects has been completed.

The following **fields of concentration** currently are offered:

American Studies
Ancient and Medieval Studies
Anthropology/Archaeology
Economics
Film and Media Studies
Foreign Languages and Literatures
History
History of Art
Labor in Industrial Society
Latin American Studies
Linguistics
Literature A (Read in English)
Literature B (Read in a Foreign Language)
Music
Philosophy
Political Science
Psychology
Religious Studies
Russian Studies
Science, Technology, and Society
Sociology
Theatre Arts
Urban Studies
Visual Art and Design
Women's Studies
Writing

Students interested in exploring or registering for a field of concentration should speak with an advisor designated by that field. Descriptions of the offerings of each field and a list of advisors may be obtained at the appropriate department headquarters or at the Humanities, Arts, and Social Sciences Information Office, Room 14N-408, (617) 253-4441.

HASS Information

For detailed information on distribution subjects or on the concentration requirements in any field, and for assistance with any aspect of the Humanities, Arts, and Social Sciences (HASS) Requirement, students should visit the HASS Information Office, Room 14N-408, (617) 253-4441.

Distribution Subjects

Humanities, Arts, and Social Science Distribution subjects are humanistic in orientation, of broad general interest, with a subject matter clearly drawn from one or more of the disciplines in the Humanities, Arts, and Social Sciences. Such subjects meet in sections small enough to allow discussions in which every student can participate, and — except for some art subjects — they call for a substantial amount of writing.

Almost all distribution subjects are without prerequisites and are appropriate for students at all levels. Students are encouraged, though not required, to take one or two distribution subjects in their freshman year, in order to begin satisfying the Institute requirement and to sample offerings of different fields.

Students are free to take more than the necessary minimum of three distribution subjects; those taken in excess of the minimum may be used as electives toward completion of the eight-subject requirement or in some cases, with the approval of the relevant field, may be accepted as part of a program of concentration. Note, however, that in no case may more than one subject in a given category or field be counted toward both distribution.

Beginning in academic year 1988-89, the distribution component of the Humanities, Arts, and Social Science Requirement (**HASS-D**) will provide increased intellectual structure and cohesion. The **HASS-D** requirement is meant to complement the General Institute Requirement in Science, emphasizing modes of inquiry and discourse that are qualitative and contextual. **HASS-D** subjects aim to develop substantive knowledge and analytical skills. They are to have a broad intellectual range and include a generous view of the alternative and often competing assumptions, perspectives, and intellectual tendencies in the field. They are to incorporate, where appropriate, materials and insights drawn from the full range of contemporary scholarship, including that on women, minorities, and non-Western cultures.

Distribution Requirement for Entering Students.
Undergraduates who enter as of academic year 1988-89 *must* take three **HASS-D** subjects from List A, which has been classified into five categories. Each category consists of subjects that are appropriate for students who may never take another subject in that area of learning, and the five categories together offer a range of choices suited to the different interests, abilities, and preparations of MIT undergraduates. Specifically, students must take *one* distribution subject from categories 1 or 2, which have a content within the humanities, and *one* distribution subject from categories 4 or 5, which have a content within the social sciences. The third distribution subject must be taken from one of the three remaining categories.

List A contains the subjects offered for **HASS-D** credit:

List A (**HASS-Distribution** System)

1. **Literary and Textual Studies.** This category consists of subjects devoted to the interpretation of texts, to literary traditions, and to genres.

21.003	Introduction to Fiction
21.004	Major Poets
21.005	Introduction to Drama
21.006	American Literature
21.009	Shakespeare
21.021	Comedy
21.044	New World Literature
21.211	Introduction to French Literature
21.239	Introduction to German Literature
21.289	Introduction to Contemporary Hispanic Literature
21.735	Writing and Reading the Essay
21.736	Writing Across the Cultures

2. **Language, Thought, and Value.** Subjects in this category focus on the study of concepts, principles, and modes of expression basic to our efforts to understand individuals and their place in the universe.

21.001	Great Books I: Homer to Dante
21.002	Great Books II: Renaissance to Modernity
21.008	The Bible
21.048	Darwin and Design
21.204	French IV
21.234	German IV
21.264	Russian IV
21.278	Spanish IV
24.00	Introduction to the Problems of Philosophy
24.01	Philosophy and Public Affairs
24.04J	Justice [17.115J]
24.07	Classics in the History of Philosophy
24.09J	Classics in Political Philosophy [17.113J]
STS 011	Ideas of Power in American Literature, Art, and Culture
†WC 108RE	Religions of Asia

3. **The Arts.** Subjects in this category may be drawn from music, the visual arts, drama and dance, and film. They may be historical and analytical, or they may be more directly concerned with the creation of art.

4.601	Topical Studies in the History and Theory of Art
4.605	Introduction to the History and Theory of Architecture
21.010	Film and Literature
21.031	The Film Experience
21.60	Introduction to Music
21.611J	Music and Art: Context for Hearing and Seeing [21.591J]
21.622	Western Music after 1750
21.623	Music of the Near and Far East
21.625	Vivaldi, Bach, and Handel
21.636	Jazz
21.641	Harmony and Counterpoint I

†Wellesley College course

4. **Cultures and Societies.** Subjects in this category focus on human societies by examining forms of social, cultural, economic, political, and religious organization and behavior.

9.00	Introduction to Psychology
11.165	Law and Public Policy
14.63	Labor in Industrial Society
17.201J	Politics and Public Policy [11.007J]
17.241	Introduction to the American Political Process
17.403	American Foreign Policy in a Changing World
17.577	The Politics of Change in the Third World
21.50	Introduction to Anthropology
21.503	Introduction to Archaeology: Paths to Civilization
21.506	Evidence and Argument in Anthropology
21.530J	The Contemporary Family [SP 456J]
SP 401	Introduction to Women's Studies

5. **Historical Studies.** Subjects in this category focus on the development of peoples, institutions, or countries over a considerable period of time.

21.351	The Ancient World: Rome
21.353	The Emergence of Europe, 1000-1300
21.361	Europe in the 20th Century
21.392	War, Money, and Sex: Topics in American History
21.465	Family, State, and Economy in East Asian History
STS 001	Technology in American History
STS 002	The Scientific Revolution

Distribution Requirement for Continuing Students.
Continuing students (who entered before academic year 1988-89) can satisfy the Distribution Requirement under the new **HASS-D** system or under the old **HUM-D** (Humanities Distribution) system, by taking three subjects from three different fields on List B. List B includes both **HUM-D** and **HASS-D** subjects. Note, however, whereas **HASS-D** subjects can be used to satisfy the **HUM-D** requirement, **HUM-D** subjects cannot be used to satisfy the **HASS-D** requirement. Continuing students can also satisfy the **HUM-D** requirement with subjects already taken from the list that appeared in the 1987-88 Bulletin. (Students who entered before academic year 1987-88 may complete the **HUM-D** requirement with subjects from the list in the 1986-87 Bulletin, by petitioning the School of Humanities and Social Science by add date of the term in which the subject is taken.)

List B contains the subjects offered for **HUM-D** credit:

List B (**HUM-Distribution** System)

Anthropology/Archaeology

21.50	Introduction to Anthropology*
21.503	Introduction to Archaeology: Paths to Civilization*
21.506	Evidence and Argument in Anthropology*
21.530J	The Contemporary Family [SP 456J]*
21.540	Technology and Culture

Economics

14.63	Labor in Industrial Society*
14.71	Topics in Economic History

Film and Media Studies

21.010	Film and Literature*
21.031	The Film Experience*

Foreign Languages

21.204	French IV*
21.234	German IV*
21.264	Russian IV*
21.277	Spanish III
21.278	Spanish IV*

History

21.350	The Ancient World: Greece
21.351	The Ancient World: Rome*
21.352	The Middle Ages I
21.353	The Emergence of Europe: 1000-1300*
21.356	History of the Western World I: 1500-1815
21.357	History of the Western World II: 1815-1970
21.361	Europe in the 20th Century*
21.369	Marx, Darwin, and Freud
21.376	Imperial and Revolutionary Russia: Culture and Politics
21.390	American History to 1865
21.391	American History Since 1865
21.392	War, Money, and Sex: Topics in American History*
21.411	American Ideas and Culture: The Modern Age, 1920-1980
21.416J	American Women's History [SP 420J]
21.450	The History and Culture of the African Heritage
21.460	East Asian History: China
21.461	East Asian History: Japan
21.465	Family State and Economy in East Asian History*
21.480	The Middle East, Islam, and the West
21.481	The Middle East in the 20th Century

Linguistics and Philosophy

24.00	Introduction to the Problems of Philosophy*
24.01	Philosophy and Public Affairs*
24.04J	Justice [17.115J]*
24.07	Classics in the History of Philosophy*
24.08	The Human Mind
24.09J	Classics in Political Philosophy [17.113J]*
24.900J	The Study of Language [21.321J]

Literature A[1]
(Read in English)

21.001	Great Books I*
21.002	Great Books II: Renaissance to Modernity*
21.003	Introduction to Fiction*
21.004	Major Poets*
21.005	Introduction to Drama*
21.006	American Literature*
21.008	The Bible*
21.009	Shakespeare*
21.021	Comedy*
21.022	Tragedy
21.044	New World Literature*
21.048	Darwin and Design*
21.101	The American Novel
21.296	Introduction to European and Latin American Fiction
21.297J	Sex Roles in Fiction: Europe and Latin America [SP 432J]
21.304	Modern European Drama
†WC IT211	Dante (in English)

*Indicates HASS-D subject (which also can be found in List A).
†Wellesley College course

Literature B[1,2]
(Read in the Foreign Language)

21.211 Introduction to French Literature*
21.216 French Culture and Society II: From the Occupation to the Mitterand Years
21.239 Introduction to German Literature*
21.240 German Culture and Society: 1750-1914
21.285 Introduction to Spanish Culture
21.287 Twentieth-Century Latin American Literature
21.289 Introduction to Contemporary Hispanic Literature*

Music

21.60 Introduction to Music*
21.611J Music and Art: Context for Hearing and Seeing [21.591J]*
21.622 Western Music after 1750*
21.623 Music of the Near and Far East*
21.625 Vivaldi, Bach, and Handel*
21.631 Symphonic Music
21.636 Jazz*
21.641 Harmony and Counterpoint I*

Political Science

17.107 Introduction to Political Theory: Individual and Community
17.201J Politics and Public Policy [11.007J]*
17.241 Introduction to the American Political Process*
17.243 American Politics and Social Change
17.403 American Foreign Policy in a Changing World*
17.543 Political Change in Latin America
17.577 The Politics of Change in the Third World*
17.707 Mass Communication and American Culture

Religious Studies

†WC RE107 Crises of Belief in Modern Religion
†WC RE108 Religions of Asia*
†WC RE262 The Formation of Islam

Science, Technology, and Society

STS 001 Technology in American History*
STS 002 The Scientific Revolution*
STS 006 History of 19th- and 20th-Century Science
STS 008 American Science Since the 1930s
STS 009 Military Enterprise and Technological Change
STS 011 Ideas of Power in American Literature, Art, and Culture*
STS 019 The Profession of Engineering

Sociology

†WC SO102 The Sociological Perspective
†WC SO103 Social Problems

Urban Studies

11.006J American Society: Values, Institutions, and Variety [17.257J]
11.013J American Urban History I [21.412J]
11.014J American Urban History II [21.413J]
11.165 Law and Public Policy*

Visual Art and Architecture

4.601 Topical Studies in the History and Theory of Art*
4.605 Introduction to the History and Theory of Architecture*
4.642 19th-Century Art
4.651 20th-Century Art
4.802 Visual Form and Expression
4.872 Creative Seeing

Women's Studies

SP 401 Introduction to Women's Studies*

Writing

21.735 Writing and Reading the Essay*
21.736 Writing Across the Cultures*
21.755 Writing and Reading Short Stories
21.760 Writing and Reading Poems
21.777 The Scientific Essay

Elective Subjects

The remainder of the eight-subject requirement, above and beyond Distribution and Concentration, may be fulfilled by the approved subjects in the humanities, arts, and social sciences. These elective subjects may be chosen from among most undergraduate subjects offered in the School of Humanities and Social Science, a substantial number of subjects in the School of Architecture and Planning, and a smaller number from the other Schools. (Please note, however, that subjects in the Sloan School of Management cannot be used to satisfy the HASS Requirement unless the subject description specifically indicates it may be used for this purpose.) Appropriate subjects taken by cross-registration at Harvard University or Wellesley College may also count toward the requirement; however, a petition must be submitted. **Graduate subjects** (designated "G") may be used to satisfy the requirement only by petition, which must include the instructor's signature.

Further information on elective subjects may be found in the *Guide to the Humanities, Arts, and Social Sciences,* available in the Humanities, Arts, and Social Sciences Information Office, Room 14N-408.

1
Students may choose only *one* Distribution subject in Literature, *either* from list A *or* B.

2
Students who have taken any third- or fourth-level foreign language subject as a Distribution subject may not take a subject from Literature B to satisfy the Distribution Requirement, unless it is in a different foreign language.

Science Distribution Requirement

The Science Distribution Requirement is met by taking three subjects designed for this purpose. Available subjects are listed below. No more than one of the subjects used to fulfill the requirement can be taken in the student's own department, and no more than two of the three subjects can be used to satisfy the student's Departmental Program. (For Classes entering MIT prior to September 1986, students fulfill the requirement by studying subjects totaling 36 units, of which no more than 12 units may be taken in subjects offered by a student's own department). Subjects designated "J," which are offered jointly by faculty members in the student's own department, also fall under the departmental limitation. If 3.091 or 5.11 is used to satisfy the General Institute Requirement in Chemistry, then it cannot be used for the Science Distribution Requirement. Science Distribution subjects normally are taken in the second year, but students who have the proper prerequisites may begin taking them in the first year.

Through Science Distribution subjects, the student can broaden and deepen the educational foundation in basic science begun in the first-year program. These subjects are designed to give each student the opportunity to proceed further in areas already studied, or to explore other areas of potential interest.

The available Science Distribution subjects vary in approach and emphasis. Some give a systematic introduction to the fundamental concepts and principles of a field; others illustrate, through examples, some of the attitudes, concerns, and methods that are characteristic of professional work in a field.

Most departmental programs require 48 units in the second year. In many cases, subjects required by a department are also on the list of Science Distribution or Laboratory Requirement subjects. Thus students following a particular Departmental Program may simultaneously satisfy some part of the Science Distribution and Laboratory Requirements.

Science Distribution Subjects

1.00	Introduction to Computers and Engineering Problem Solving (3-1-8)
1.04	Behavior of Physical Systems I (3-2-7)
1.12	Computer Models of Physical and Engineering Systems (3-0-9)
1.32	Introduction to Engineering Geology (3-3-6)
1.59J	Materials of Construction (3-0-9)
2.01	Mechanics of Solids (4-0-8)
2.02	Introduction to Systems Dynamics (4-0-8)
2.101	Computer Models of Physical and Engineering Systems (3-0-9)
2.20	Fluid Mechanics (4-0-8)
2.40	Thermodynamics (4-0-8)
3.00	Thermodynamics of Materials (4-0-8)
3.05	Computer Models of Physical and Engineering Systems (3-0-9)
3.07	Introduction to Ceramics (3-0-6)
3.091	Introduction to Solid-State Chemistry (5-0-7)[1]
3.10	Chemical Physics of Materials (4-0-8)
3.11	Mechanics of Materials (4-0-8)
3.143J	Materials of Construction (3-0-9)
4.30	Basic Structural Theory (3-3-6)
5.11	Principles of Chemical Science (5-0-7)[1]
5.12	Organic Chemistry I (5-0-7)
5.60	Chemical Thermodynamics (4-0-8)
5.61	Physical Chemistry (4-0-8)
6.002	Circuits and Electronics (4-2-9)
6.018	Statistical Mechanics and Thermodynamics (4-0-8)
6.034	Artificial Intelligence (4-0-8)
6.041	Probabilistic Systems Analysis (4-0-8)
6.071	Introduction to Electronics (4-2-6)
7.01	General Biology (4-0-8)
7.05	General Biochemistry (5-0-7)
8.03	Physics III (5-0-7)
8.04	Quantum Physics I (5-0-7)
8.20	Introduction to Special Relativity (2-0-7)
8.211	Introduction to Quantum Physics (5-0-7)
8.243	Modern Optics (3-0-9)
8.263	Physics of Fluids (3-0-9)
8.282	Introduction to Astrophysics and Astronomy (3-0-9)
8.286	The Early Universe (3-0-9)
8.291J	Planetary Science I (3-0-9)
8.292J	Planetary Science II (3-0-9)
8.293J	Dynamical Astronomy (3-0-9)
10.11	Computer Models of Physical and Engineering Systems (3-0-9)
10.13	Chemical Engineering Thermodynamics I (4-0-8)
12.01	Introduction to Geology (3-4-5)
12.02	Chemistry and Physics of Minerals and Rocks (3-4-5)
12.107	Introduction to Geophysics (3-0-9)
12.113	Astronomy: Stars and Galaxies (3-0-9)
12.114	Astronomy: Solar System (3-0-6)
12.126J	Dynamical Astronomy (3-0-9)
12.131J	Planetary Science I (3-0-9)
12.132J	Planetary Science II (3-0-9)
12.21	Physics of the Ocean (3-0-9)
13.00	Computer-Aided Hydrostatics and Hull Surface Definition (3-3-6)
13.51	Computer Models of Physical and Engineering Systems (3-0-9)
14.30	Introduction to Statistical Method in Economics (4-0-8)
15.053	Introduction to Management Science (4-0-8)
15.852	Principles of Dynamic Systems I (3-0-9)
16.001	Unified Engineering I (5-2-5)
16.008	Computer Models of Physical and Engineering Systems (3-0-9)
18.03	Differential Equations (4-0-8)
18.05	Introduction to Probability and Statistics (4-0-8)
18.06	Linear Algebra (3-0-9)
18.063	Introduction to Algebraic Systems (4-0-8)
18.313	Probability (4-0-8)
18.440	Probability and Random Variables (4-0-8)
18.703	Modern Algebra (3-0-9)
18.710	Abstract Linear Algebra (3-0-9)
22.006	Computer Models of Physical and Engineering Systems (3-0-9)
22.02	Introduction to Applied Nuclear Physics (3-0-9)
22.03	Engineering Design of Nuclear Power Systems (3-0-9)
22.04	Radiation Effects and Uses (2-1-9)



[1] Not acceptable as Science Distribution Subject, if taken to fulfill the General Institute Requirement in Chemistry.

Laboratory Requirement

The Laboratory Requirement of one subject of at least 12 units or two subjects of at least 6 units is met by enrolling in subjects expressly designed for this purpose. The available subjects are listed below. The Laboratory Requirement is normally fulfilled in the first two years.

A typical laboratory subject offers the student an opportunity to set up and carry out experiments dealing with phenomena of the natural world. Under faculty supervision, the student plays a substantial role in planning a) the design of the experiment, b) the selection of the measurement technique, and c) the procedure to be used for validation of the data.

Hypotheses are formulated and then tested by comparing them with the results of the experiments. The student then compares and discusses the experimental results in terms of the current state of knowledge and prepares progress and final reports of the work.

The laboratory subjects call for a major commitment of the student's attention to one or a few experimental problems and emphasize as much as possible work of project type rather than routine experimental exercises. They are designed to stimulate the student's resourcefulness and ideas.

The Laboratory Requirement is not intended primarily to teach specific techniques for later experimental work, provide broad coverage of a particular field, or be a complement to a specific subject. The laboratory subjects are planned to give each student, at an early stage of the educational experience at MIT, an opportunity to work on one or a few experimental problems, exercising the same type of initiative and resourcefulness as a professional would in similar circumstances.

Laboratory Requirement Subjects

1.101	Decision Analysis Laboratory (3-4-5)
1.102	Transportation Laboratory (0-3-3)
1.105J	Structural Engineering Laboratory (0-3-3)
1.106	Laboratory Projects in Environmental Fluid Mechanics (0-3-3)
1.107	Aquatic Chemistry and Biology Laboratory (2-6-4)
1.53	Constructed Facilities Project Laboratory (0-3-3)
2.671	Measurement and Instrumentation (2-3-7)[1]
2.672	Project Laboratory (1-3-2)
2.86	Manufacturing Processes and Systems (3-3-3)[2]
3.081	Materials Laboratory (2-6-7)
4.071J	Design with Microclimate (3-6-3)
4.315J	Structural Engineering Laboratory (0-3-3)
4.41	Building Technology Laboratory (0-4-2)
5.310	Laboratory Chemistry (2-8-2)
5.311	Introductory Chemical Experimentation (2-8-2)
6.101	Introductory Analog Electronics Laboratory (3-8-1)
6.111	Introductory Digital Systems Laboratory (3-7-2)
6.121J	Bioelectronics Project Laboratory (2-8-2)
6.141	Energy and Electromechanical Systems Project Laboratory (0-10-2)
6.151	Semiconductor Devices Project Laboratory (0-12-0)
6.161	Modern Optics Project Laboratory (2-8-2)
6.162	Image Transmission Systems Project Laboratory (0-12-0)
6.163	Strobe Project Laboratory (2-8-2)
6.182	Psychoacoustics Project Laboratory (3-4-5)
7.011	Introduction to Experimental Biology (2-8-5)
8.11	Physics Project Laboratory I (1-6-5)
8.12	Physics Project Laboratory II (1-6-5)
8.287J	Observational Techniques of Optical Astronomy (3-4-5)
9.50	Research in Brain and Cognitive Sciences (2-8-2)
9.63	Laboratory in Cognitive Science (0-6-6)
11.185J	Design with Microclimate (3-6-3)
11.188	Social Research Methods (3-6-3)
12.066	Analysis of Geological Materials (2-6-4)
12.117J	Observational Techniques of Optical Astronomy (3-4-5)
13.901	Ocean Engineering Laboratory I (1-5-0)
13.902	Ocean Engineering Laboratory II (1-5-0)
14.31	Econometrics (3-4-5)
15.301	Managerial Psychology Laboratory (2-6-4)
16.622	Experimental Projects II (1-7-4)
17.203	Political Science Laboratory (3-5-4)
22.069	Undergraduate Plasma Laboratory (1-8-3)
22.09	Principles of Nuclear Radiation Measurement and Protection (2-6-4)
HST 575J	Bioelectronics Project Laboratory (2-8-2)

1 Students taking 2.671 (12 units) receive 6 units of laboratory credit.

2 Students taking 2.86 (9 units) receive 6 units of laboratory credit.

Physical Education Requirement

The Institute expects all students to complete the Physical Education Requirement by the end of the sophomore year. By that time, a student should have accumulated the required eight points of physical education credit (four courses) and should have passed the swimming test or taken a beginning swimming course. Credit may be earned by participation in the Intercollegiate Program (four points for each sport in season). A maximum of four points (two points per year) may be earned by physical activities within the ROTC programs.

There are Advanced Credit Examinations available for physical education credit in a number of different activities, including a physical fitness test. Two points of credit are awarded to students who pass one of these proficiency tests. Appointments are made with the Director of Physical Education. These exams *must* be completed no later than one week prior to the last day of classes for that year. A maximum of four points may be gained through Advanced Credit Examinations.

Sophomore transfer students must complete four of the eight-point Physical Education Requirement, plus the swim test. Transfer students beyond the sophomore year are *not* subject to the requirement.



Independent Activities Period

Program Information

The program consists of both individual activities and team sports, with the major emphasis placed on the development of skills that can be utilized in later life. A student who elects individual sports such as golf, tennis, sailing, or squash will receive a strong background in the fundamentals of the sport. Instruction in physical education classes often leads to intercollegiate or intramural participation.

Physical education courses are offered in four quarters — two quarters for each semester — and also during the Independent Activities Period. Students register for these courses in the gymnasium on the day of or the day after the academic registration and on a specific date halfway through each semester.



First Quarter:

Aerobic dance, archery, ballet I, II, jazz, partner dance, introduction to dance, touch football, ultimate frisbee, golf, lacrosse, pistol, rugby, sailing, scuba, sculling, exercise fitness, swimming (beginning), table tennis, T'ai Chi, tennis (beginning and intermediate), weight training, and yoga.

Second Quarter:

Aerobic dance, badminton, basketball fundamentals, ballet I, II, jazz, partner dance, introduction to dance, fencing, hockey, judo, karate, pistol, exercise fitness, skating (beginning), squash, swimming (beginning and intermediate), table tennis, weight training, and yoga.

IAP:

Aerobic dance, badminton, ballet I, jazz, partner dance, fencing, hockey, box lacrosse, pistol, exercise fitness, skating (beginning), figure skating, squash, tennis (intermediate and advanced).

Third Quarter:

Aerobic dance, basketball, ballet I, II, jazz, partner dance, fencing, figure skating, hockey, judo, karate, pistol, scuba, exercise fitness, skating (beginning), squash, swimming (beginning, advanced beginning, and intermediate), volleyball, weight training, advanced lifesaving (part 1), and yoga.

Fourth Quarter:

Aerobic dance, archery, ballet I, II, jazz, partner dance, ultimate frisbee, lacrosse, golf (beginning), pistol, sailing, scuba, sculling, exercise fitness, softball, squash, swimming (beginning and advanced techniques), tennis (beginning and intermediate), weight training, advanced lifesaving (part 2), and yoga.

Upon entering MIT, each student must submit a record of a medical examination and take a swimming test. Students who fail the swimming test are expected to take beginning swimming. If the medical examination indicates any disability that might limit physical activities, athletic requirements may be modified after consultation with the MIT Medical Department.

Independent Activities Period (IAP) is a three-and-one-half week period in January when faculty members and students are freed from the rigors of regularly scheduled classes for flexible teaching and learning and for independent study and research. IAP is part of the academic program of the Institute — the "1" in MIT's "4-1-4" academic calendar. Students are encouraged to explore the educational resources of the Institute by taking specially designed subjects, arranging individual projects with faculty members or by organizing and participating in IAP activities. They may also pursue interests independently either on or off campus.

Activities

More than 600 activities are offered each year on a wide range of subjects, both academic and nonacademic. A list of subjects offered for credit during IAP is published in early fall. Other activities are organized mostly by individual volunteers during the fall. Activities may be organized or attended by anyone at the Institute: faculty, student, or employee.

Students find organizing IAP activities a rewarding challenge. For many, it is their first opportunity to develop and teach a program from their own ideas. In doing so, they acquire organizational and leadership skills that prove invaluable to their careers.

The *IAP Activities Planning Sheet* offers tips on organizing an activity, and provides an application form for publicizing the activity in the *IAP Guide*. Funds are available from the Institute and individual departments and organizations to help defray expenses. New and student-led activities receive priority from the Institute's IAP Activities Fund.

Tuition, Room, and Board

Full-time students in either the first or second semester do not have to pay additional tuition or room fees to the Institute during IAP. Students can purchase additional points on their fall-term meal plan to cover IAP, or they can purchase a new plan for IAP and the spring term at the beginning of January.

Academic Credit and Grades

A student may earn academic credit by doing work under the direction of a faculty member for a subject listed in the MIT course catalogue. The total cumulative credits a student can earn for all subjects is limited to six credit hours, except by special authorization. A department head may approve the awarding of up to 12 units in a single subject, but in all other cases, undergraduates must petition for approval from the Committee on Curricula, and graduate students from the Committee on Graduate School Policy. Credits received by freshmen during IAP are not counted toward their credit limits for the spring or fall term.

A student wishing to receive credit must work out the details individually with a faculty supervisor who will choose an appropriate subject listed in the course catalogue and determine how much credit is to be offered. In keeping with the generally unstructured nature of IAP, there is no formal registration process.

During IAP, all work done for credit under a special problem subject number is graded pass/fail. However, if a regular subject is offered in intensive form, letter grades may be given.

Students are asked to remind their faculty supervisors that their IAP grades must be turned in by the last day of IAP. Grade reports will be sent to the students and to their departments at the beginning of the spring semester. Students not receiving grade reports when expected should check promptly with their supervisors or the Registrar's Office to be sure the grades are submitted and recorded. Late credit and grades must be submitted on special reporting forms by the end of the following spring term. IAP grades will not be accepted after the end of the academic year.

Veterans' Benefits

Full-time students receiving Veterans' benefits have been certified for the entire academic year. Because the period between the first day of winter vacation and the beginning of the second term is more than a calendar month, VA regulations require that IAP be treated as a separate term, much the same as Summer Session. To ensure uninterrupted benefits for IAP, students must notify the Student Financial Aid Office, Room 5-119, (617) 253-4971, by December 1, of their intent to attend IAP full time. Students must receive credit, i.e., a letter or pass/fail grade, to be entitled to VA benefits. Anyone who receives VA benefits for IAP but fails to earn sufficient credit will have to return the money. Veterans should make sure their instructors turn in their grade sheets to the Registrar's Office on the last day of IAP.

Special Students

Applications for special-student status solely for IAP will not be accepted. Special students admitted to the first or second term do not automatically have IAP privileges. Those admitted by the Director of Admissions must consult the Admissions Office concerning their status during IAP. Former students readmitted as special students by the Committee on Academic Performance (CAP) or the Office of the Dean for Student Affairs (ODSA) must consult the appropriate office for permission to participate in IAP. If the special student has paid full tuition during the first term or is admitted to do so in the second, there will not be an additional tuition charge for IAP. If the student has not been paying full tuition, he or she will be charged either the minimum special student fee or the amount necessary to bring tuition for the term up to full tuition.

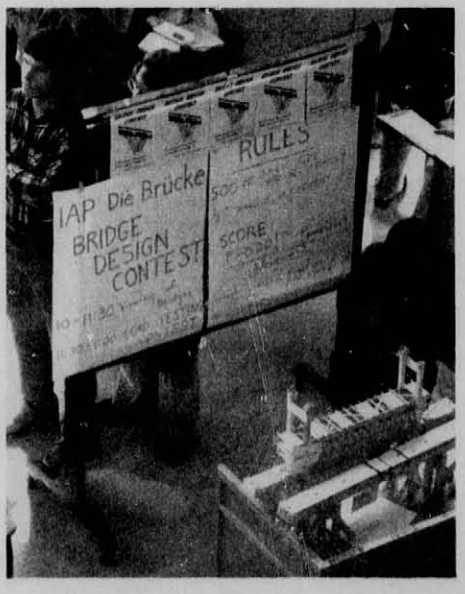
Special students wanting credit for IAP work should consult the Registrar's Office, Room E19-341, (617) 253-4781, if they were admitted by CAP or ODSA, or the Admissions Office if they were admitted by the Director of Admissions.

Student Exchanges

A one-for-one exchange between an MIT student and someone from another school is permitted during IAP, provided the students themselves assume responsibility for all arrangements, travel expenses, and any additional tuition and living expenses. If the other school waives tuition for the MIT student, MIT will reciprocate. The MIT Admissions Office may also waive the application fee if the other school does so.

MIT students wishing to set up an exchange should contact the IAP Office, Room 7-103, (617) 253-1668. Students from outside MIT should ask the appropriate office on their own campus to contact the IAP Office. Because MIT will not admit special students solely for IAP, students from other schools can attend IAP only as part of a one-for-one exchange.

The Institute's regular cross registration with Wellesley College remains in effect during IAP. MIT students are encouraged to take advantage of their flexible schedules during IAP to participate in Wellesley's winter term. In return, Wellesley students are invited to join IAP activities.



Admissions

Freshman Admissions

Secondary School Preparation

The majority of undergraduate men and women enter MIT as members of the freshman class, directly following completion of secondary school studies. Most good public, parochial, and independent secondary schools in the United States and equivalent schools in other countries provide suitable preparation for the student who takes full advantage of the opportunities that such schools afford. The efforts of secondary schools to achieve regional accreditation are encouraged by MIT.

The preparatory course in high school should be a broad one. The applicant should be able to read with intelligence and sensitivity and to express ideas clearly in oral and written form.

In mathematics, emphasis should be on thorough mastery of fundamental principles, operations, and definitions rather than on covering a wide range of topics. The applicant must have sufficient preparation for the study of calculus.

Work in the sciences should stress basic concepts and quantitative understanding, both in classroom work and in the laboratory setting. Chemistry and physics are particularly appropriate preparation for the freshman-year science subjects at MIT.

MIT encourages the study of history and of foreign language in depth. The choice of languages should be guided by the educational opportunities open to each student, by special interests or cultural ties, and by the nature of his or her probable future work.

MIT expects that its applicants will have taken the broadest, most rigorous program available to them in high school. Ideal preparation for study at MIT would include English (four years), history/social studies (two or more years), mathematics through trigonometry or beyond (four years), laboratory sciences (biology, chemistry, and physics), and a foreign language. Interested students whose high school program does not match this in every detail are also urged to apply, since the selection of an entering class with broad interests will be guided as well by the quality of the applicant's work; by special strengths; and by apparent promise on grounds of intellect, character, and particular goals.

Application Procedures

Applicants are encouraged to write during their junior year for information. Candidates in their last year of high school must complete the application process by January 1 of the year of intended entrance. Early Action (available to citizens and permanent residents of the US only), has a November 1 deadline. There is a $40 application fee. Notices concerning the admission decision will be mailed in early April. MIT may limit enrollment in particular fields of study to balance resources with student interest.

Personal Conferences (Interviews)

Each applicant for admission to the freshman class is required to have a personal conference with a designated member of the MIT Educational Council near the applicant's home. Council members are MIT graduates who have been selected for their ability to represent MIT and for their interest in young people.

Each applicant will be referred for a conference to a member of the Council. This conference is an essential part of the final application and must take place between May 1 of the junior year and December 15 of the year prior to entrance.

Prospective applicants and their families are welcome at the Admissions Office Monday through Friday between 9 am and 4 pm. Student-guided tours of the campus leave the Information Center each weekday (except holidays) at 10 am and 2 pm. Students and parents are welcome at the Admissions Office after the tour for a group session with a member of the staff.

Project Interphase

In order to help newly admitted underrepresented students make a successful transition from high school to the pace and style of MIT, a special summer session called Project Interphase is available. This program offers subjects in math, science, and the humanities, which build on the regular entrance requirements. For more information, interested students may write The Office of Minority Education, MIT, Room 7-143, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139.

Deferred Admissions

Occasionally, students wish to take a year off between secondary school and college. In such cases, we recommend following normal admissions procedures, as if going directly on to college, and then requesting deferral. If during the "deferred" year students take post-secondary school academic work approximating a full course load, they must reapply as transfer students rather than matriculate as deferred freshmen.

Advanced Placement

MIT has always encouraged students to move ahead academically according to their capabilities. It offers four procedures by which students entering from secondary schools may receive credit and/or placement: 1) the College Board Advanced Placement Program; 2) GCE A-levels, the International Baccalaureate and other foreign exams; 3) college transcript; and 4) Advanced Standing Examination at MIT.

Students who take college-level subjects offered in their schools in cooperation with the College Board Advanced Placement Program should take the appropriate three-hour examinations administered by the Board each year in May and instruct the Board to send the scores to MIT. Degree credit for MIT subjects, and, where appropriate, advanced placement, is given on the basis of a high achievement on the tests (normally a score of four or five). High scores on the humanities, arts, and social sciences tests will enable students to receive credit (9 units) applicable to the unrestricted elective requirements only. This credit will **not** reduce the General Institute Requirement of eight one-term subjects in the areas of Humanities, Arts, and Social Sciences.

In some secondary schools, selected students take college-level subjects at a local college. Such students may submit an official transcript from the college showing subjects taken and grades earned in order to receive MIT credit under the regular college transfer procedures.

Students may be notified of the credit offered before registration. If notification has not been received, verify credit before registration with the Director of Advanced Placement, Admissions Office, Room 3-108.

International Undergraduate Admissions

Entrance Examinations

All candidates are required to take the following tests: the SAT or ACT and three one-hour Achievement Tests in 1) Level I or Level II Mathematics, 2) Physics or Chemistry or Biology, 3) English or History. (Test requirements vary for international students. See the section on Entrance Examinations for International Applicants later in this chapter for more details.)

These examinations are offered in the principal cities of the United States and abroad. The test dates, locations, and fees for the SAT and Achievement Tests are outlined in an Information Bulletin that may be obtained from most guidance offices or by writing directly to the College Board, Box 592, Princeton, New Jersey 08540. Residents of western North America, Mexico, Australia, Pacific Islands, Japan, and China should apply to the College Board, Box 1025, Berkeley, California 94701. Information about the ACT may be obtained by writing to American College Testing Service, Box 168, Iowa City, Iowa 52243.

Candidates for admission for September 1989 must have completed the SAT or ACT and the three Achievement Tests by the January 1989 testing date. The SAT or ACT or up to three achievements may be taken on any scheduled test date. Note that the closing dates for registration are usually four to six weeks (five to seven weeks outside the United States) before the test date. The testing agency should be requested to send all scores directly to MIT. A student taking physics or chemistry in the junior year should probably take the achievement test in that subject during the spring of that year.

Early Action (Available only to citizens and permanent residents of the US)

MIT requires a complete set of application materials before considering a candidate for admission. A student who takes all the required tests by the November test date and files all of the application material by November 1 of the senior year may request the Committee on Admissions to review the application by mid-December. If the test scores, school grades through the junior year, and other qualifications are so excellent that the applicant will clearly be acceptable later, the Committee will offer admission immediately. If it feels that it should compare the application with those of other candidates, it will hold the application until the usual time in April. A student who seeks early consideration in this way is free to file applications at other colleges and, if offered admission at MIT, is not required to reply to the Institute before the candidates' reply date in early May. This, therefore, is not an "early decision" plan in the usual sense.

The MIT undergraduate student body includes many citizens of other countries. These students normally join the freshman class after completing secondary school at the highest level. Students are encouraged to plan on completing the Higher School Certificate, the General Certificate of Education at the Advanced Level, the Baccalaureate, the Maturite, or the Gymnasium, even though decisions on admission to MIT are made in April, prior to the time when most exams are normally taken.

All citizens of foreign countries, except foreign citizens attending secondary schools in the United States, should begin the application process as outlined below.

Application Procedures

Students should write to the Director of Admissions at least a year before they plan to enter MIT for information about application procedures. The Admissions Office will send a Preliminary Application form, which should be returned promptly. Final application materials will be forwarded to those whose preliminary form is approved. All documents must be completed in English or accompanied by attested translations of the original into English. In order to receive consideration, the Final Application must be completed and returned by January 1, and the required tests (including, if appropriate, the Test of English as a Foreign Language — TOEFL) must be taken on or by the January test date. All students are urged to register for the tests at least six to eight weeks in advance of the testing date.

Preliminary Application forms or initial letters of inquiry about admission received after November 15 will be too late for the next fall term.

Personal Conferences

Applicants will receive instructions about arranging a personal conference with a local MIT alumnus. If no one is available in the home area, the interview will be waived.

Facility in English

Lectures, laboratory sessions, and written or oral examinations at MIT are conducted in English. All applicants must present evidence of their ability to carry on their studies in English.

Entrance Examinations for International Applicants

The College Board tests listed in the Entrance Examination section of this chapter are the required entrance examinations. If English is not the applicant's native language, the following group of tests may be substituted: the Test of English as a Foreign Language (TOEFL) and two Achievement Tests — Physics, Chemistry, or Biology — and either the Math Level I or Level II Achievement Test.

TOEFL is administered by the Educational Testing Service. Students wishing to take the TOEFL must do so no later than the January test date; an earlier test date is preferable. Write directly to the Educational Testing Service, Princeton, New Jersey 08540, USA, for registration material and information.



College Transfer Admissions

Students who have completed two or more terms with high standing at a recognized college, university, engineering school, or junior college and who are entitled to honorable dismissal may be admitted to MIT by transfer.

A transfer student's eligibility for admission will be determined by the Committee on Admissions after a review of his or her record. MIT may not be able to accept applications in a given year for those departments whose enrollments exceed educational resources. The Department of Electrical Engineering and Computer Science is currently not open to transfers. This condition may change, however. In the meantime, other departments at the Institute offer curricula that may satisfy the student's interest; the Admissions Office welcomes inquiry from all transfer applicants.

Transfer applications may be submitted at not less than one-year intervals. It is not customary to admit as a transfer a student with only three terms needed to complete the degree.

Transfer applicants will be asked to take the tests prescribed in this chapter's section on entrance examinations for freshman applicants if they have not already done so. Transfer applicants from foreign countries are admitted only for September.

International transfer students should read carefully the sections on Entrance Examinations and Entrance Examinations for International Applicants in this chapter.

Application Procedures

College students considering transfer to the Institute should file a Preliminary Application for Admission with Advanced Standing three months before the final application deadline. These forms can be obtained from the Admissions Office. The Director of Admissions will advise the applicant of those parts of the regular entrance requirements which must be fulfilled and will arrange to have the final application materials sent.

The applicant must assure that the following documents are submitted:

1
A completed Application for Admission with Advanced Standing, indicating all subjects that will have been completed at the time of transfer, and a nonreturnable fee of $40. Final applications should be submitted by April 1 for entry in September and by November 15 for entry in February.

2
A certified transcript of the college record to date, including a statement of good standing. A certified statement covering subjects subsequently taken should be sent as soon as it is available.

3
Catalogue pages describing all subjects which will have been completed.

4
Three evaluation reports, including two from faculty instructors and one from the Dean of Students or the applicant's chief faculty advisor.

5
A report from the secondary school attended. The report should be made on the form provided with the Final Application and should be sent directly from the secondary school to the Director of Admissions.

6
Standardized test reports, as appropriate.

As soon as the completed application has been reviewed, the applicant will be informed of the decision. In some cases, action may be deferred until final grades are available.

Students who wish to have transfer credit posted to their MIT transcripts should submit confirmation of approved credit (with necessary signatures of approval) to the Registrar's Office by the end of the 11th week (drop date) of their first term of registration.

Applications for Financial Aid

An intention and a wish to apply for financial aid may be shown on the admission application form in space provided for that purpose.

Advanced Credit

Students admitted by transfer may expect to receive credit for subjects of study completed elsewhere that are substantially equivalent to corresponding Institute subjects. A grade above the lowest passing grade is necessary.

A student in another college contemplating later transfer to MIT should plan a program of studies to include as much as possible of the mathematics, physics, and humanities as is included in the typical first two years of MIT.

Applicants admitted with advanced standing in architecture will be placed in the design sequence in accordance with their performance on their first problem.

All remaining questions concerning credits must be settled within two weeks after the opening of the academic year. In these cases, the student should consult the Director of Admissions.

Costs for Undergraduate Students

Special Student Admissions

The Institute can accept a limited number of undergraduates who wish to carry on special studies and who are not degree candidates at MIT. The students enroll as Special Students; they enjoy most of the privileges of the regular student but are not eligible for campus housing or financial assistance from MIT. Special Student status is granted for *one term only,* and a new application for this status is required for any successive terms. Admission as a Special Student does not carry any implication for other applications. Applicants must present academic credentials of high quality or evidence of professional experience relevant to the proposed program. Admission is subject to available places in the classroom, laboratory, or studio.

The Director of Admissions will supply application forms upon request. There is an application fee of $40 for the first application; it is not required for renewal applications within one academic year.

Deadlines for filing applications are August 1 for fall term, January 1 for spring term, and May 1 for summer term.



Undergraduate student costs for the academic year 1988-89 at MIT will be about $19,750. This includes tuition, comprehensive health care services at the MIT Medical Department,[1] and an **estimate** for the costs of room and board, books, supplies, and personal expenses. Cost of travel obviously varies significantly and is not included. The cost of books and supplies, clothes, laundry, recreation, and other personal necessities vary widely, depending upon interests, tastes, and needs, but typically total about $1,710. There are many kinds of dining and housing arrangements at MIT and the range of student expenses for room and board is broad. The Student Financial Aid Office uses a standard allowance of $4,640 for room and board. Thus, total costs for most undergraduates during the 1988-89 academic year will be in the range of $18,400 to $20,000 (excluding cost of travel), depending upon specific choices.

The following are the basic **tuition and fees** at MIT for the academic year 1988-89 (which are reviewed and likely to increase each year):

Tuition	$13,400
Hospital and Accident Insurance Policy[2]	336

The tuition for all regular undergraduates in the first and second terms is $6,700 per term. Full tuition in either term of the current year covers the January Independent Activities Period. Tuition rates for the Summer Session are published each year in the *Summer Session Catalogue,* available in March.

Regular undergraduate students who have permission to take only a few subjects are initially charged full tuition. They may then apply to have their tuition charged at the rate of $215 per unit with the approval of the Faculty Advisor and, if not a degree candidate, with the additional approval of the Dean for Student Affairs. In such cases, there is a minimum fee of $1,290 for subjects and a minimum of $560 for S.B. thesis. Upon recommendation of a department, the Dean for Student Affairs, in the case of an undergraduate student, may set a special tuition rate in unusual circumstances.

Special Students are charged at the rate of $215 per unit taken either for credit or not for credit. This unit fee applies up to a maximum of $6,700 per term and is subject to the following minimum fees:

Members of the MIT Community[3]	$1,290
Other Special Students	1,935

Cooperative programs offered by MIT provide industrial and research experience through a series of work assignments interwoven with regular study at the Institute. The tuition fees for cooperative programs are as follows:

Aeronautics and Astronautics,
Course XVI-B and Course XVI-C
Mechanical Engineering, Course II-B
Nuclear Engineering, Course XXII-A
Ocean Engineering, Course XIII-C
June-August (15 months), $13,400

Electrical Science and Engineering or Computer Science and Engineering,
Course VI-A
Engineering Internship Program
July 1 to June 30, $13,400

Materials Science and Engineering,
Course III-B
September-August, $13,400

In each case, the first $6,700 is due on the date when the first-term tuition is normally due, and the additional $6,700 is due on the date when the second-term tuition is normally due. Upon recommendation of the Department, a special tuition rate for any cooperative program may be set in an unusual case.

1
Payment of the tuition fee entitles all regular and special registered students to comprehensive health care services at the MIT Medical Department, including consultation with a wide range of specialists, diagnostic studies, and hospitalization in the MIT Infirmary. Charges are made for completion of preentry medical forms and immunizations, obstetrical care, routine eye examinations, elective podiatry, contact lens service, hearing aid evaluations, ear piercing, dental care, missed appointments, contraceptive devices, prescription drugs, and those surgical procedures and outside diagnostic tests which should be covered by the student's hospital and accident insurance policy.

2
The MIT Student Insurance covers hospitalization (other than in the MIT Infirmary) due to accidents or illness. The insurance is required for all students, unless they can demonstrate that they have equivalent coverage through another insurance program. A medical insurance plan for a student's spouse and children is also available. The additional cost of insurance coverage for the spouse for outside hospital care is $1,038. Hospitalization insurance for one or more children may be purchased for $336. A student withdrawing during a term may cancel this insurance and receive a credit, as of the end of the month when cancelled, by filing a request at the Student Insurance Office.

3
Includes Special Students who are full-time employees of the Institute or who are dependents of full-time employees or regular students.

Financial Aid

Grants, Loans, and Employment

For Aeronautics and Astronautics, Course XVI-B, during the regular term at the plant, students pay per unit tuition for eight units of 16.80.

A student withdrawing before the start of a term is not charged any tuition for that term, and any tuition payments previously made for that term will be refunded. Students withdrawing during the first or second term are charged one-twelfth of the stated tuition for the term for each week from the starting date of the term, with a minimum two-week charge. A student is financially obligated to the Institute for the tuition appropriate to the program approved by his or her Faculty Advisor at the beginning of the term. Any subsequent reduction in fees is based on the date that cancellation of a subject or withdrawal from the Institute is effected. At that time, any excess payments which the student has made will be refunded.

If the student receives financial aid through one of the Title IV Federally based student financial aid programs, and aid is reduced as a consequence of the reduced tuition, the total amount of Title IV aid (minus work earnings) is divided by the total amount of aid awarded (minus earnings), to determine the amount to be credited toward the student's charges and the amount to be returned to the Title IV programs.

Miscellaneous Fees

Application fee for undergraduate admission	$40
Late registration fee	25
Fee for late filing of degree application	25

Processing Charges for Late Changes in Registration

A late change in registration, which requires the approval of the appropriate faculty committee, is defined as adding a subject after the fifth week or dropping a subject during the last three weeks of a term. The processing charge for late changes is $25 for one subject or $30 for more than one subject in a petition. There is an additional charge of $25 for a retroactive change after the end of the term.

The miscellaneous fees and processing charges listed above are nonrefundable, unless levied in error.

Payment of Tuition and Other Charges

The Bursar's Office gathers, bills, and collects student charges and provides a student account statement of that activity. These charges originate in the offices from which the student receives Institute services. The student account statement, mailed monthly when activity has occured on an account, will reflect the charges (of tuition, fees, housing, library fees, etc.) and payments (by cash, finanical aid, tuition awards, etc.) for Institute costs, additional amounts due, and payment deadlines.

Payment in full or a satisfactory arrangement for payment is due prior to the beginning of each term, in August and January. New charges and credits that occur after the initial statement will appear on subsequent statements. If a student anticipates that he or she may not be able to pay their entire account by the August or January deadlines, the payment options available from the Bursar's Office should be considered. Participation in the Bursary Payment Plan allows an installment payment arrangement over four months each term (three months during the summer). The interest rate is currently .83% per month (or 10% annual percentage rate). The MIT Parent Loan Plan allows parents to borrow funds for four years of educational expenses and to extend the repayment over a longer period of time. Currently up to $16,000 per year ($64,000 maximum) may be borrowed at a 10% annual percentage rate. Contact the Bursar's Office in Room E19-215 or by calling (617) 253-4132 for the forms needed to participate in these programs.

If a student fails to make satisfactory arrangements for payment and has amounts outstanding after a payment due date, that balance will be subject to late fees of 1.5% per month (or 18% annually). Additionally, outstanding balances at the end of a term may prevent registration for the following term or graduation, if the student is a degree candidate.

The staff of the Bursar's Office should be contacted for assistance with payment options, questions about your statement, or alternatives, should payment difficulties arise, and with issues related to long-term educational or short-term emergency loans.

The Student Financial Aid Office provides grants and loans based on the financial need of the individual student, as determined by analysis of a statement of family financial condition. This will be provided by means of the Financial Aid Form of the College Scholarship Service. A copy of the most recent parental Federal tax return is also required in support of aid applications.

MIT is fortunate in having received gifts from many benefactors, alumni, and friends to help support the educational needs of MIT students. There are currently more than 500 such scholarships from which student aid is annually drawn. Additionally, there are about 60 loan funds that have been established for special purposes. The Student Financial Aid Office reviews applications and makes awards from the most suitable Institute grant and loan resources. Applicants need not request aid from a specific fund. Any need that is not met by a grant may be offset by long-term loans or employment.

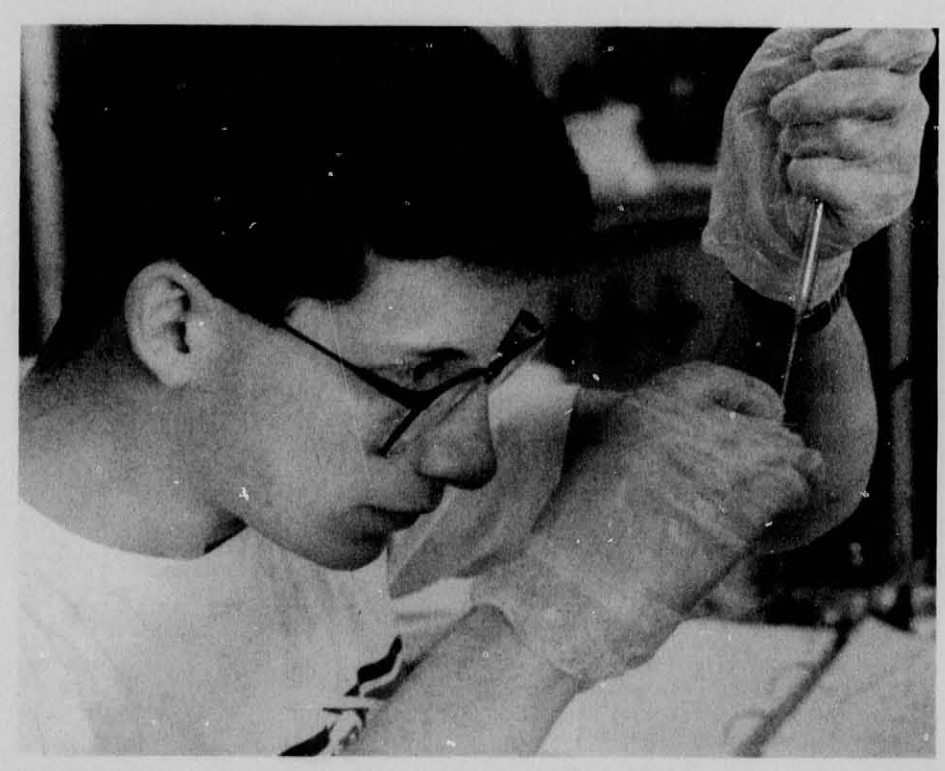
Students are expected to work and/or borrow to meet the first incremental portion of their need. Student loan funds allow the student to pay part of the cost of his or her education on long-term credit under favorable financial terms. However, loan fund capital is limited, and MIT student loans are granted to meet systematically calculated financial need only. Undergraduate loans are provided from several sources, including the Perkins Loan Program, the Guaranteed Student Loan (GSL) Program, and the Institute's own Technology Loan Fund.

Applications for Financial Aid

Jobs are not assigned; rather, students are expected to arrange employment most suitable to their own talents and available time. The Student Employment Office maintains listings of positions to assist students seeking jobs. Employment is usually available on campus in dining facilities, residence halls, offices, libraries, and laboratories. Listings of off-campus positions are also available. Students' earnings from part-time work depend on experience, and, of course, availability of time.

All students considering MIT are strongly urged to explore all areas of financial assistance including government scholarship and loan programs. A number of states sponsor scholarship programs for residents, and information concerning eligibility may usually be obtained from secondary school guidance counselors. The Federal Guaranteed Student Loan Program for students and the Parent Loans for Undergraduate Students Program are administered by individual states. Local banks and lending institutions should be able to answer initial inquiries concerning the availability of loans under these programs.

Parents of students considering MIT might also want to request additional information about the Institute's Parent Loan Plan (briefly described in the Payments section) and other long-term financing options.



Entering Freshmen

Students who wish to be considered for financial aid should complete the appropriate form included with the Application for Admission. In addition, the Financial Aid Form (FAF) appropriate to the applicant's state of residence must be submitted to the College Scholarship Service. An application for admission is not prejudiced by an application for aid. The two decisions are entirely separate — need criteria have no bearing on admissions, and admissions criteria have no part in determining qualifications for aid. There is no reason to be deterred from applying concurrently to MIT for admission and aid.

International Students

MIT has small amounts of grant and loan funds that are made available to exceptionally well-qualified international undergraduate students who demonstrate financial need. International students who wish to be considered for financial aid should complete and return the appropriate form included with their admissions material by the February date specified.

Because financial aid funds are severely limited, students should seek aid from sources other than MIT. **International students should make all arrangements for their financial obligations to MIT for their entire stay in the United States before leaving their countries.**

Transfer Students

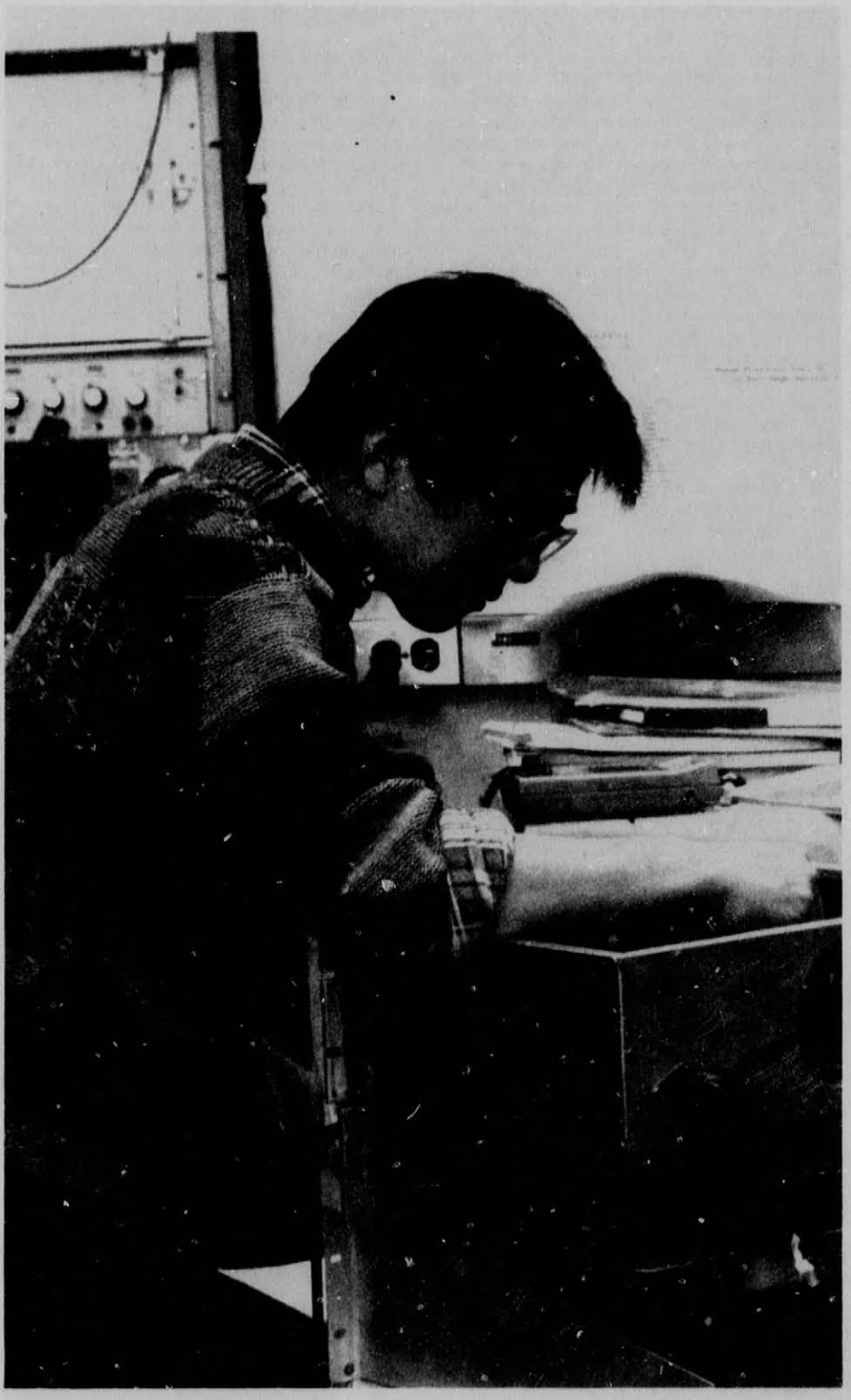
Transfer applicants who wish to be considered for financial aid may obtain an application form and detailed instructions by completing the Request for MIT Financial Aid Application included in the Admissions packet.

Upperclass Students

MIT awards are made on an annual basis, and recipients are required to reapply each year for continued assistance in the following year. Upperclass financial aid applications are sent to the term addresses of current aid recipients in early February; upperclass students who have not been receiving assistance may also apply at this time by obtaining the new forms from the Student Financial Aid Office. Part of the application process requires a copy of the most recent parental Federal tax return, and all applicants are expected to apply concurrently for a Federal Pell Grant, a state grant where applicable, and for any and all renewable grants received in prior years.

A student's eligibility for MIT undergraduate *grant* funds will end when the student receives an initial degree, or after the equivalent of eight terms, whichever occurs first. Eligibility for Pell Grants may continue beyond the eighth term, under some conditions, but ends with the taking of an initial degree.

Eligibility for undergraduate loans continues through all undergraduate programs; and, of course, a student becomes eligible for the higher loan maximums that pertain to graduate students upon admission to a graduate program.



Graduate Education at MIT











Graduate Education at MIT

For almost a century, the MIT Graduate School has provided an ideal environment for advanced study by faculty and students working together to extend the boundaries of knowledge. The Institute has traditionally been a national leader in engineering graduate education, and its doctoral programs in mathematics and the physical and life sciences have also attained national prominence. In addition, top-ranked graduate programs in economics; political science; linguistics; science, technology, and society; architecture; urban studies; and management have broadened the spectrum of graduate education.

The most important factor in the effectiveness of the graduate programs at MIT is the quality of the faculty. MIT is proud of its nationally and internationally recognized faculty of scholars and academic leaders, who are also effective teachers and research collaborators.

The broad scope and high quality of its graduate education have made MIT an international leader. About a third of its graduate students come from foreign nations. In recent years, an increasing number of minority students have participated in academic work at all levels; the Institute has seen over the last few years an increasing number of women attending MIT's graduate programs. This broad representation of students from diverse backgrounds contributes greatly to the richness of the MIT community and to the excellence of the Graduate School.

Graduate education at MIT places special emphasis on the relevance of science and technology to the complex problems of society. Such problems typically require an interdisciplinary approach involving expertise in several different departments.

Extensive resources for graduate study have developed naturally at MIT from a long tradition of emphasis on contributions to new knowledge. The wealth and diversity of teaching and research resources are described in the departmental sections (Chapter VII).

Although most graduate students find their interests served by programs available within a single department, many elect to work in interdisciplinary fields (described in Chapter VI), which may reach into two or more departments and involve work in any of MIT's laboratories. Special committees provide guidance in certain areas such as biomedical engineering, economics and urban studies, environmental engineering, instrumentation, management of technology, medical engineering, medical physics, operations research, technology and policy, transportation, and health policy and management. In other fields, interdepartmental programs are administered by ad hoc committees appointed for each student and approved by the Dean of the Graduate School.

MIT's libraries are a major resource for graduate study. Comprehensive collections are available in fields where MIT concentrates its teaching and research efforts. Through participation in the Boston Library Consortium, graduate students, faculty members, and research staff have access to extensive research collections outside the Institute.

Another resource for graduate study is the cross-registration programs with Harvard University, Wellesley College, and joint degree programs with the Woods Hole Oceanographic Institution. Limited study opportunities are also available at Brandeis University, Tufts University, and Boston University. Details are given later in this chapter.

Graduate students are encouraged to use MIT's extensive athletic facilities. Teams composed of both undergraduate and graduate students participate in intercollegiate competitions, and the intramural athletic program.

Graduate students also share in the cultural and social activities and recreational facilities at MIT. Concerts and dramatic performances are frequently given by Institute groups and professional performers. Leaders in many fields give lectures and seminars on the campus, which are open to all members of the Institute community. MIT students also take advantage of the numerous cultural and intellectual opportunities in the Boston area, including free admission to the Boston Museum of Fine Arts and the Museum of Science. A more detailed description of campus activities can be found in Chapter II of this catalogue.

Independent Activities Period

During the January Independent Activities Period (IAP), graduate students may pursue their own interests, including thesis research and preparation for qualifying exams. They also may lead or participate in activities specially organized for this three and one-half week period.

Graduate students should read the section on IAP in Chapter III of this catalogue for details concerning credit, VA benefits, and special student status.

Organization of the Graduate School

The administration of the Graduate School rests with the President, the Provost, and the Associate Provost of the Institute, the Dean and Associate Dean of the Graduate School, and the Committee on Graduate School Policy, whose members include a faculty member from each department offering graduate degrees, and two representatives from the Graduate Student Council. The Institute has a single faculty that is responsible for both undergraduate and graduate instruction.

Each department exercises a large measure of autonomy for its graduate programs, under general guidelines established for the Institute as a whole. Each department has a departmental committee on graduate students, including one or more graduate registration officers, to administer department and Institute graduate procedures.

More detailed information about the organization, rules, regulations, and procedures of the Graduate School is given in the *Graduate School Manual.* Copies are available from the Office of the Dean of the Graduate School (Room 3-138, 617/253-4860) and from department graduate offices.



General Requirements for Graduate Degrees

Master's Degrees

Graduate students may pursue work leading to any of the following degrees: Doctor of Philosophy, Ph.D.; Doctor of Science, Sc.D.; Engineer's degrees; Master of Science, S.M.; Master of Architecture, M.Arch.; and Master in City Planning, M.C.P. Graduate programs are described in individual department statements in Chapter VII.

Each graduate student is officially enrolled in one department or Course. The programs are not limited, however, to subjects offered in a single department. Subjects and research programs may be chosen from several departments, with the approval of the departmental faculty advisor to ensure that the overall program is integrated and well balanced with respect to a major field of study.

A student who expects to come to MIT for an advanced degree after earning an undergraduate degree elsewhere should give careful attention to undergraduate prerequisites as outlined by each department or program elsewhere in this catalogue. For more specific information, a student should consult the department or program in which he or she wishes to enroll.

MIT degrees are "residence" degrees in the sense that a major portion of the work must be done on campus in association with the faculty, other graduate students, and the Institute community. The amount of time required to attain any one degree varies.

Degrees are awarded by the Corporation of the Institute upon the recommendation of the faculty. Favorable faculty action is based upon approval by the Committee on Graduate School Policy on recommendations from the appropriate departmental committees on graduate students.

Master of Science With and Without Specification

For the degree of Master of Science, the student must have satisfactorily completed a program of study of at least 66 units, of which 42 units shall be "A" subjects, and a thesis, approved by the department in which he or she is enrolled. If 34 units of "A" subjects and the thesis are in a single approved program, as determined by a departmental committee on graduate students, the degree will be recommended with specification in this program; otherwise, the degree will be recommended without specification. The same high standard of academic performance in a program approved by a departmental committee on graduate students is required for either degree.

The choice of area of specialization must be approved by the committee on graduate students of the department in which the student is enrolled. Approval of the entire program must be obtained from this committee and from the student's faculty advisor. A special interdepartmental committee, approved by the Dean of the Graduate School, may be appointed to supervise a program in an interdepartmental field.

The satisfactory completion of the Master's degree requires the student to be in residence as a full-time regular graduate student for a minimum of one regular academic term (not the summer session). Every degree candidate working on a thesis must register for thesis in all semesters during which his or her thesis research or writing is actually in progress and during the term his or her name appears on the degree list.

Master of Architecture

The graduate degree of Master of Architecture is awarded upon the satisfactory completion of a program of study of at least 164 subject units approved by the Department of Architecture, of which 96 units must be in "A" subjects, and the completion of a thesis acceptable to the Department of Architecture. The candidate must also have been in residence for a minimum of four regular academic terms. A student who enters without previous experience in a department of architecture may take as long as eight academic terms to complete the degree.

Master in City Planning

For the degree of Master in City Planning, the student must have satisfactorily completed a minimum of 120 units, of which at least 42 units must be "A" subjects. The student must also have completed a thesis acceptable to the Department of Urban Studies and Planning, and have been in residence for a minimum of two regular academic terms.

Simultaneous Registration for Two Master's Degrees

Single thesis. This degree plan is intended for qualified graduate students who seek academic recognition in two professional fields that, although distinct, have a substantial interdisciplinary connection. The interdisciplinarity is implemented both by a balanced choice of academic subjects, made with the advice of each of two departments, and by selection of the thesis topic.

To satisfy the minimum requirements for the program, the student must complete (in addition to thesis units) at least 132 subject units, of which 66 units are unique to each department. At least 42 of each group of 66 units must be graduate "A" subjects. In those instances where, for a single regular Master's degree or program, a department or program has established unit requirements in excess of the foregoing minima, the department or program requirements prevail. Such excess of units in one department may not be applied to the program in the other department.

Students pursuing a Master in City Planning in addition to a second Master's degree must have both programs approved in the usual way, but the subject units for the M.C.P. can be lowered at the discretion of the Department of Urban Studies and Planning.

Individuals who wish to qualify for a Master of Science degree in Real Estate Development, in addition to a Master of Architecture or Master in City Planning degree, will be required to satisfy all the subject requirements of each program. Specifically, candidates for the M.Arch. degree must take 164 subject units (of which 96 units must be "A" subjects), and M.C.P. degree candidates must take 120 subject units (of which 42 units must be "A" subjects). Individuals who wish to qualify for the Master's degree in Real Estate Development also must take at least 66 subject units unique to this program, of which at least 42 units must be "A" subjects. Students may submit a single thesis provided it is acceptable to the graduate committees of each program. It is expected that such dual-degree candidates will be in residence at least one term longer than expected if enrolled in a single-degree program.

Participation in a dual-degree program is limited to students who are already registered in one department and who meet the admissions criteria of the second department. At least two

regular terms prior to completion of the program, the student must submit to each department a statement of educational objectives along with a detailed program plan that includes a description of the proposed thesis topic. The total program must meet with the approval of each department and a petition approved by the Dean of the Graduate School describing the program must be filed with the Registrar.

The thesis research must be done under the supervision of an approved member of one of the two participating departments, with the other department providing a thesis reader. The thesis must be of superior quality. The single thesis cannot be used to satisfy the thesis requirements of any additional graduate degree programs.

In special cases, the Standing Committee of an approved Interdisciplinary Program may act in lieu of one of the two participating departments.

Two theses. Occasionally an individual, already admitted to the Graduate School, may wish to simultaneously pursue two distinct Master's programs, fulfilling the thesis requirement with a separate thesis for each degree program. In such cases, the usual unit requirements for each program apply separately. Registration for two degrees is contingent upon approval by the second department of a request for admission. Such a request can be initiated by a petition approved by both departments and approved by the Dean of the Graduate School.

Simultaneous Award of Bachelor's and Master's Degrees

An undergraduate student of the Institute who is enrolled as a candidate for the Bachelor's degree may be admitted by a department as a candidate for the Master's degree. Students must register as graduate students for at least one regular academic term (not summer session) to be recommended for the simultaneous award of the Bachelor's and Master's degrees. The thesis submitted for the Master's degree may also be accepted by the department in fulfillment of the undergraduate thesis requirement, if any. A student wishing to pursue this type of academic program must submit an application for the Graduate School in the usual way, as well as file a petition with the Registrar, which has been approved by the student's undergraduate faculty advisor and the graduate registration officer of the appropriate department.

Engineer's Degrees

The program for an Engineer's degree requires more advanced and broader competence in engineering and science subjects than for the Master's degree, but with less emphasis on original research than a doctoral program. In general, the Engineer's degree requires two academic years beyond an undergraduate degree.

The following Engineer's degrees are awarded: Chemical Engineer (Chem.E.); Civil Engineer (C.E.); Electrical Engineer (E.E.); Engineer in Aeronautics and Astronautics (E.A.A.); Environmental Engineer (Env.E.); Materials Engineer (Mat.E.); Mechanical Engineer (Mech.E.); Metallurgical Engineer (Met.E.); Naval Engineer (Nav.E.); Nuclear Engineer (Nucl.E.); Ocean Engineer (Ocean E.).

Satisfactory completion of a program of advanced study and research approved by the appropriate department or interdepartmental committee of the School of Engineering is required. The minimum program consists of at least 162 subject units (exclusive of thesis units) and the completion of an acceptable thesis. The candidate must also have been in residence for a minimum of two regular academic terms. Registration is required of every degree candidate working on a thesis in all periods during which the thesis research or writing is actually in progress and during the term his or her name appears on the degree list. A department may accept a Master's thesis of superior quality for the Engineer's degree only if the student intends to use that document to fulfill the requirements of a single Master's degree.



Doctoral Degrees

MIT offers the degrees of Doctor of Science and Doctor of Philosophy, interchangeably, in the engineering and science departments (except biology) and in the fields of medical engineering and medical physics. The degree of Doctor of Philosophy is awarded in architecture, biology, economics, linguistics, management, philosophy, political science, brain and cognitive sciences, urban studies and planning, and from Whitaker College. These degrees certify creditable completion of an approved program of advanced study in addition to a research dissertation of high quality based on original research.

The two Institute requirements for a doctorate are: 1) completion of a program of advanced study, including a general examination, and 2) completion and oral defense of a thesis on original research.

Graduate study and research leading to a doctoral degree must be pursued under the direction of the Committee on Graduate School Policy for at least four academic terms. In some cases, the required period of residence may be reduced, but in no instance can it be reduced to less than two regular academic terms and one summer session.

A student is enrolled in a program of advanced study and research approved by the department. The thesis research is in this same area, but the program often includes subjects reaching into several departments. If the field requires substantial participation by two or more departments, an interdepartmental faculty committee, approved by the Dean of the Graduate School, should be appointed to supervise the student's program.

Each doctoral candidate has a general examination in his or her program of study at such time and in such manner as the departmental or interdepartmental committee approves. This examination consists of both oral and written parts.

Thesis

A doctoral thesis requires at least one full-time academic year of research, but most doctoral research efforts take a substantially longer time. Each doctoral candidate is required to register for thesis in all periods during which work is actually in progress.

The investigation must be carried out under the supervision of an MIT faculty member or senior staff member approved by the department. Work already accomplished elsewhere that has not been approved by a department cannot be accepted in fulfillment of the thesis requirement.

An oral examination on the thesis will be held after it has been submitted and evaluated by the examiners.

Non-Resident Doctoral Thesis Research Status

While doctoral thesis research is ordinarily carried out while the student is in residence at the Institute, on some occasions it may be essential or desirable that the student be absent from the campus during a period of his or her thesis research or writing. Permission to become a non-resident doctoral candidate must be sought from the Dean of the Graduate School at least one month prior to Registration Day of the term during which the student wishes to register in this category. Consult the *Graduate School Manual* for additional information on non-resident status.

Minor Program

Although there is no Institute requirement of a minor for the doctoral degree, certain departments require that candidates take a number of subjects outside their major field.

Language Proficiency

There is no Institute language requirement; however, several departments require that a candidate be able to read or speak one or two foreign languages with intermediate competence. Typically, a student may satisfy the requirement in one of three ways: 1) by fulfilling the requirement before entrance by passing one or more intermediate or advanced subjects with a grade of C or better; 2) through examination by the Foreign Languages and Literatures Section of the Department of Humanities; or 3) by taking a two-term subject in a language or languages offered by the Foreign Languages and Literatures Section of the Department of Humanities. Depending on student demand, the Section offers a choice of two-term language subjects, stressing the ability to read or to speak in French, German, Russian, or Spanish.

For the purpose of the second alternative, the Section gives written examinations in French, German, Russian, and Spanish once each term. Examinations in other approved languages are arranged individually upon request.

Cross Registration at Other Institutions

Harvard University

A regular, full-time graduate student at MIT may enroll to take subjects (exclusive of thesis) at Harvard without paying additional tuition, provided that this enrollment does not exceed one-half of his or her total registration for the term. Included in the above category are MIT full-time Special Graduate Students. This cooperative arrangement is not applicable to the summer session.

Requests for registration under this cooperative arrangement must be approved by the MIT department of registration and should be confined to subjects that are not offered at the student's own institution. Students will not be allowed to attend classes where additional registrants put an undue load on the instructors. The procedures to be followed are given in the *Graduate School Manual.*

Wellesley-MIT Exchange

Graduate students are eligible to participate in the Wellesley-MIT Exchange Program. Wellesley courses are not considered "A" subjects, but may be accepted for graduate credit toward a student's degree with the approval of the department. For details about the Exchange, see the description of the Program in Chapter III of this catalogue.

Woods Hole Oceanographic Institution

MIT, in conjunction with the Woods Hole Oceanographic Institution, offers graduate degree programs in oceanography and oceanographic engineering. All decisions, from admission to the conferring of the joint degree, are made by consensus of MIT/WHOI joint discipline committees. The programs in oceanography involve the Departments of Biology and Earth, Atmospheric, and Planetary Sciences at MIT. The oceanographic engineering programs involve the MIT Departments of Civil, Chemical, Electrical, Materials Science, Mechanical, and Ocean Engineering. Information regarding the program may be obtained from the MIT Joint Program Office or the Education Office at WHOI.

Boston University

A cross-registration agreement has been made between the MIT Departments of Economics and Political Science and the African Studies Program of Boston University. Details of the procedures to be followed are similar to those for Harvard-MIT cross-registration.

Brandeis University

A cooperative arrangement also exists between the MIT Department of Urban Studies and Planning and the Florence Heller Graduate School for Advanced Studies in Social Welfare at Brandeis University. Cross-registration is restricted to one or two subjects per term in the areas of social welfare at Brandeis and urban studies at MIT.

Tufts University

A cross-registration agreement exists between MIT and the School of Dental Medicine at Tufts University. The program is restricted to specific graduate subjects at each institution.



Admissions

Regular Graduate Admissions

A Regular Graduate Student is an applicant who has been admitted to the Institute and is registered for a program of advanced study and research leading to any of the post-baccalaureate degrees offered by MIT. A student registered in a program of study leading to the simultaneous award of the degrees of Bachelor of Science and Master of Science must apply to the Graduate School and be registered as a graduate student for at least one academic term (not the summer session) of his or her program of study.

To be admitted as a Regular Graduate Student, an applicant must have received a Bachelor's degree or its equivalent from a college, university, or technical school of acceptable standing. Applicants are evaluated by the department in which they propose to register on the basis of their prior performance and professional promise. These are evidenced by academic records, letters of evaluation from individuals familiar with the applicant's capabilities, and any other pertinent data furnished by the applicant. While high academic achievement does not guarantee admission, such achievement, or other persuasive evidence of professional promise, is expected.

Some engineering departments require students seeking a Doctoral degree to qualify first for a Master's degree.

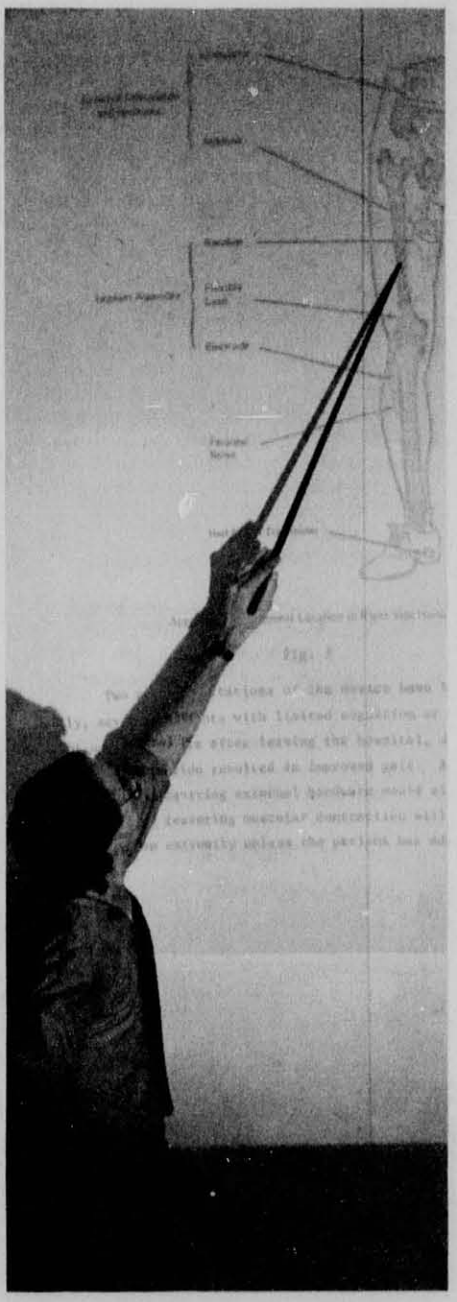
Undergraduate Requirements for Advanced Degrees

In addition to preparation in the specific field of interest, most departments require significant work in mathematics and the physical sciences, but some require as little as a year each of college-level work in these disciplines. Requirements of individual departments are given in Chapter VII of this catalogue. Students with minor deficiencies in preparation may be admitted to the Graduate School; however, deficiencies in prerequisite or general or professional subjects must be made up before the student may proceed with graduate work dependent on them.

Application Procedures

Students normally enter the Graduate School in September. However, in several departments, suitable programs can be arranged for students entering in June or February. Prospective applicants should check with individual departments about their dates for admission.

Students wishing to enter in June or September should apply on the prescribed forms by January 16 (exceptions to that deadline will be found in the application packet); candidates for admission in February should apply by November 2. However, applications submitted later may be considered if vacancies still exist. Fees will not be returned to late applicants, but may be applied to an application considered in the next term. Candidates for admission who are also applicants for financial aid should observe the same deadlines.



Applicants attending colleges or universities on the semester system should apply before the end of the fall semester for admission in June or September, and submit a transcript of fall grades as soon as it is available.

Applications for admission should be requested from the Director of Admissions, Room 3-103, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139. (Exceptions: the Sloan School of Management and the Departments of Chemistry, Physics, and Urban Studies and Planning should be contacted directly for application forms.) A $40 application fee (except for the Master's Program in the Sloan School, where the fee is $60 if applying from the US and $70 if applying from overseas) must accompany all application forms. All inquiries regarding graduate admission to the Sloan School are sent to the Directors of the Master's or Doctoral Programs (whichever is appropriate), Room E52-112, MIT, Cambridge, Massachusetts 02139. Applications for readmission after an absence of five years or more must be approved by the Dean of the Graduate School as well as the department.

Notification about admission for September is sent as soon as action is taken (usually before April 1); for February applicants, notification usually is sent as soon as the application is complete. Admission of a student who is in the final year of work toward a Bachelor's degree may be conditionally approved until subsequent evidence is provided that the degree has been awarded.

Inquiries about specific requirements for admission should be addressed to the chairman of the appropriate departmental committee on graduate students.

Examinations

Many departments require applicants to submit scores in the Aptitude Test and the appropriate Advanced Test of the Graduate Record Examination. The requirements specified by the departments are included in the MIT graduate application material. For a test application, write to the Graduate Record Examination, Educational Testing Service, Box 955, Princeton, New Jersey 08540.

The Sloan School of Management requires that all applicants, including those from foreign countries, take the Graduate Management Admission Test (GMAT). For the locations and dates at which this test may be taken, write to GMAT, Educational Testing Service, Princeton, New Jersey 08540.

International Graduate Admissions

Graduate student applicants who are citizens of countries other than the United States must have received a Bachelor's degree or its equivalent from a college, university, or technical institute. The academic record and all credentials must indicate the ability of the candidate to complete an approved program of graduate study and research. Applicants are evaluated by the academic departments. Admission is granted on a competitive basis. Competence in written and spoken English is expected.

Students whose native language is not English and whose schooling has not been predominantly in English, must take the Test of English as a Foreign Language (TOEFL). TOEFL is administered by the Educational Testing Service. Students wishing to take the TOEFL should do so no later than the November test date. A score of 575 is the minimum considered acceptable. Write directly to the Educational Testing Service, Princeton, New Jersey 08540, USA, for registration material and information.

The Final Application for Admission from International Students may be obtained from the Director of Admissions, Room 3-103, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, or, in the case of the Sloan School, from the Directors of either the Master's or Doctoral Programs, Room E52-112. Applicants must submit complete application materials to the appropriate office.

Please refer to the previous section concerning individual departmental requirements for the Graduate Record Examinations.



Special Graduate Students

A Special Graduate Student is one who usually has received a Bachelor's degree and whose intended program of study is essentially graduate in nature. Special students are not degree candidates. All applications are made through the Admissions Office. Applications for the specific subjects will be evaluated and approved by the Graduate Committee of the appropriate department(s). Admission is valid for only one term; a student must seek readmission each term to continue at the Institute. Those applying for Special Graduate Student status for the first time must pay a $40 application fee. A new fee is required after two terms. To be allowed to continue as a Special Graduate Student, satisfactory academic performance must be maintained.

The deadlines for filing Special Student applications are May 1 for the summer term, August 1 for the fall term, and January 1 for the spring term.

Applicants whose native language is not English must submit the Test of English as a Foreign Language (TOEFL) as noted in the section on International Graduate Admissions. A score of 575 is the minimum considered acceptable. The I-20 or IAP-66 will not be issued for subject registration of less than 32 units.

Admission as a Special Graduate Student does not imply any commitment on the part of the Graduate School toward an individual's admissibility to Regular Graduate Student status (degree candidate). If a Special Graduate Student is subsequently admitted as a degree candidate, subjects completed may be used in partial fulfillment of requirements for an advanced degree. The department will determine what subjects are acceptable. Registration as a Special Graduate Student does not count toward minimum residency requirements for an advanced degree nor for eligibility for non-resident status.

Correspondence concerning admission as a Special Graduate Student should be addressed to the Director of Admissions, Room 3-103, from whom application material and "Information for Special Students" may be obtained.

Graduate Student Status for Research Staff Members

In view of their full-time responsibilities on assigned research and their corresponding salary scales, staff members of the Office of Sponsored Programs (OSP), Lincoln Laboratory, or the Charles Stark Draper Laboratory may not be full-time Regular Graduate Students, but may, under certain conditions, be granted the status of Special Graduate Student. However, an OSP appointee or an employee of the Lincoln Laboratory or the Draper Laboratory who desires to work for an advanced degree must be admitted as a Regular Graduate Student and complete the residency and other requirements of the degree program to which the individual has been accepted. This individual may not continue to hold a research staff appointment nor can any research work while employed be included as part of the thesis for an advanced degree.

Any OSP appointee or an employee of the Lincoln Laboratory or the Draper Laboratory may, by written permission from the director of the division (or his or her designate), apply for admission as a Special Graduate Student for enrollment in one subject only per term (but not thesis), either as a listener or for academic credit. Acceptance for such enrollment will be granted if, in the opinion of the instructor, the individual is qualified to undertake the subject and if section size permits. For this type of enrollment, the student will be assigned to an appropriate registration officer and will pay, whether as a student or listener, the fee established at the Special Student rate.

Other Employment

A graduate student may not interrupt an academic program to accept employment on the academic, administrative, or research staff, or as an hourly employee at MIT, the Lincoln Laboratory, or the Draper Laboratory either during the academic year or the summer, unless the approval of the department head and of the appropriate academic Dean has been obtained, and unless the work as an employee is unrelated to the student's thesis research. A thesis release form indicating such approval must be submitted to the appropriate Personnel Officer to effect such employment. A graduate student may not include in his or her thesis any material based in whole or in part upon work done while holding an academic or research staff appointment.

Costs for Graduate Students

The following are the basic tuition and fees at MIT for the academic year 1988-89 (which are reviewed and likely to increase each year):

Tuition[1]	$13,400
Hospital and Accident Insurance Policy[2]	336

The tuition for all regular graduate students, including graduate student staff, in the first and second terms is $6,700 per term, except for students entering the Sloan Master's Program in September 1988 and thereafter for whom the tuition is $7,250 per term. Full tuition in either term of the current year covers the January Independent Activities Period. The minimum term tuition charge for registration for doctoral thesis upon readmission as a resident student is $10,050, if not registered during the preceding regular term. The tuition for all regular graduate students including fellows, trainees, and academic staff in the 1988 summer session was $4,450. Special tuition rates apply to other students in the summer session. These are published each year in the *Summer Session Catalogue*, available in March.

Special Students (except in the Sloan School of Management) are charged at the rate of $215 per unit taken either for credit or not for credit. This unit fee applies up to a maximum of $6,700 per term and is subject to the following minimum fees:

Members of the MIT Community[3]	$1,290
Other Special Students	1,935

Any resident graduate student making progress toward a degree is expected to register and is considered a full-time student. If a graduate student requires only part of a term to complete the thesis, initially, full tuition for the term is charged, and adjustments to tuition are made at a later date. If the student was registered for thesis as a resident student in the immediately preceding term, regular or summer, tuition for thesis will be adjusted after acceptance by the department of the completed document on the basis of a charge of $560 per week from the starting date of the term, with a minimum of $560 for the Master's or Engineer's degree and $1,120 for the Doctoral degree. If the immediately preceding term was the summer term and if the graduate student was not registered for thesis in that summer term, but was registered for thesis in residence in the previous second term, the minimum tuition for thesis is $3,350. A student who continues to hold a fellowship, traineeship, or graduate staff appointment for the remainder of the term after delivery of the thesis continues to be regarded as a full-time student and the tuition will not be adjusted. In unusual circumstances, the Dean of the Graduate School may set special tuition rates for graduate students.

Doctoral thesis research is ordinarily carried out while the student is in residence at the Institute. However, on some occasions, it may be essential or desirable that the student be absent from the campus during a period of his or her thesis research. Permission to become a non-resident doctoral candidate must be sought from the Dean of the Graduate School at least one month prior to the opening of the term during which the student wishes to register in this category. Prior to submission, the request must be approved by the student's thesis supervisor and by the representative to the Committee on Graduate School Policy from the student's department of registration. Students who are permitted to undertake non-resident thesis research must register as Non-Resident Doctoral Candidates and pay tuition equal to approximately 15 percent of the regular full tuition ($1,000 per term for 1988-89). Following completion of the non-resident period, the student must return to resident status for completion and presentation of the doctoral thesis. If the student requires only part of this first term back in residence to complete the thesis, the tuition will be adjusted subject to a minimum of $3,350. Please consult the *Graduate School Manual* for additional information on non-resident status.

Cooperative programs offered by MIT provide industrial and research experience through a series of work assignments interwoven with regular study at the Institute. The tuition fees for cooperative programs are as follows:

Aeronautics and Astronautics, Course XVI-C
Mechanical Engineering, Course II-B
Nuclear Engineering, Course XXII-A
Ocean Engineering, Course XIII-C
June-August (15 months), $13,400

Chemical Engineering Practice,
Course X-A
September-January or February-June,
$6,700

Electrical Science and Engineering or Computer Science and Engineering,
Course VI-A
Engineering Internship Program
July 1 to June 30, $13,400

Materials Science and Engineering,
Course III-B
September-August, $13,400

In each case, the first $6,700 is due on the date when the first-term tuition is normally due, and the additional $6,700 is due on the date when the second-term tuition is normally due.

The tuition fee for Special Graduate Students in the Sloan School of Management (except for employees of the Institute or their children) is $360 per unit of registration, with a minimum charge of $3,240. There is a maximum charge of $11,160 per term for full-time special graduate students enrolled in the program. Students interested in the Management of Technology Program should consult the Sloan School of Management with regard to fees.

There is a professional activities fee of $100 per regular term in the Master's Degree Program in the Sloan School.

A student withdrawing before the start of a term is not charged any tuition for that term and any tuition payments previously made for that term will be refunded. Students withdrawing during the first or second term are charged one-twelfth of the stated tuition for the term for each week from the starting date of the term, with a minimum two-week charge. A student is financially obligated to the Institute for the tuition appropriate to the program approved by

1
Payment of this fee entitles all regular and special registered students to comprehensive health care services at the MIT Medical Department, including consultation with a wide range of specialists, diagnostic studies, and hospitalization in the MIT Infirmary. Charges are made for completion of pre-entry medical forms and immunizations, obstetrical care, routine eye examinations, elective podiatry, contact lens service, hearing aid evaluations, ear piercing, dental care, missed appointments, contraceptive devices, prescription drugs, and those surgical procedures and outside diagnostic tests which should be covered by the student's hospital and accident insurance policy.

2
The MIT Student Insurance covers hospitalization (other than in the MIT Infirmary) due to accidents or illness. The insurance is required for all students, unless they can demonstrate that they have equivalent coverage through another insurance program. A medical insurance plan for a student's spouse and children is also available. The additional cost of insurance coverage for the spouse for outside hospital care is $1,038. Hospitalization insurance for one or more children may be purchased for $336. A student withdrawing during a term may cancel this insurance and receive a credit, as of the end of the month when cancelled, by filing a request at the Student Insurance Office.

3
Includes Special Students who are full-time employees of the Institute or who are dependents of full-time employees or regular students.

his or her faculty advisor or graduate registration officer at the first of the term. Any subsequent reduction in fees is based on the date that cancellation of a subject or withdrawal from the Institute is effected. At that time, any excess payments which the student has made will be refunded.

Graduate Living Costs

Living expenses for graduate students vary widely depending on such factors as marital status, availability of resources, interests, and tastes. Monthly living costs (housing, food, and personal expenses) range $900-$1,900 for a single graduate student, $1,250-$2,650 for a married graduate student, and $1,425-$2,900 for a married graduate student with one child. These cost estimates do **not** include tuition, books, or the Hospital and Accident Insurance Policy. Campus housing for graduate students is limited and less than half of the graduate student population can be accommodated in Institute housing. On-campus dining opportunities are available to graduate students.

Miscellaneous Fees

Application fee for graduate admission	$40
Application fee for Master's Program in Sloan School of Management	
Domestic applicants	60
International applicants	70
Late registration fee	25
Fee for Doctoral degree language exam (given at an unscheduled time)	30
Fee for late filing of degree application	20
Fee for late thesis title change	20
Library processing fees	
Doctoral theses	35
All other theses for advanced degrees	23

Processing Charges for Late Changes in Registration

A late change in registration, which requires the approval of the appropriate faculty committee, is defined as adding a subject after the fifth week or dropping a subject during the last three weeks of a term. The processing charge for late changes is $25 for one subject or $30 for more than one subject in a petition. There is an additional charge of $25 for a retroactive change after the end of the term.

The miscellaneous fees and processing charges listed above are nonrefundable, unless levied in error.

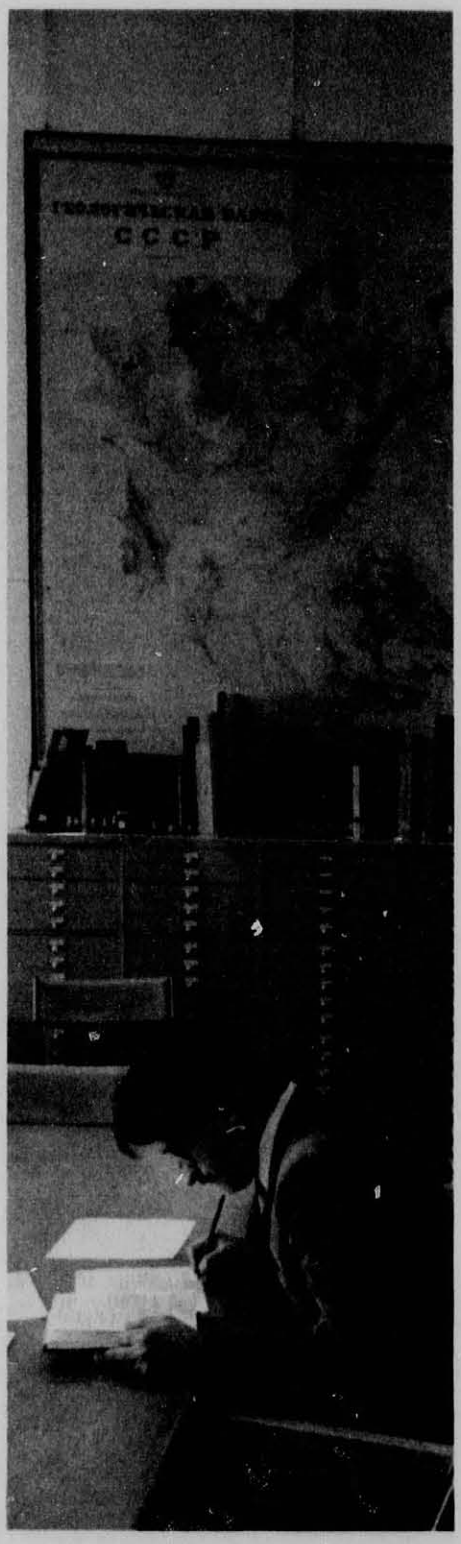
Payment of Tuition and Other Charges

The Bursar's Office gathers, bills, and collects student charges and provides a student account statement of that activity. These charges originate in offices from which the student receives Institute services. The student account statement, mailed monthy when activity has occurred on an account, will reflect the charges (of tuition, fees, housing, library fees, etc.) and payments (by cash, finanical aid, tuition awards, etc.) for Institute costs, additional amounts due, and payment deadlines.

Payment in full or a satisfactory arrangement for payment is due prior to the beginning of each term in August and January. New charges and credits that occur after the initial statement will appear on subsequent statements. If a student anticipates that he or she may not be able to pay their entire account by the August or January deadlines, the payment options available from the Bursar's Office should be considered. Participation in the Bursary Payment Plan allows an installment payment arrangement over four months each term (three months during summer). The interest rate is currently .83% per month (or 10% annual percentage rate). The MIT Parent Loan Plan allows parents to borrow funds for four years of educational expenses and to extend the repayment over a longer period of time. Currently up to $16,000 per year ($64,000 maximum) may be borrowed at a 10% annual percentage rate. Contact the Bursar's Office in Room E19-215, or by calling (617) 253-4132.

If a student fails to make satisfactory arrangements for payment and has amounts outstanding after a payment due date, that balance will be subject to late fees of 1.5% per month (or 18% annually). Additionally, outstanding balances at the end of a term may prevent registration for the following term or graduation, if the student is a degree candidate.

The staff of the Bursar's Office should be contacted for assistance with payment options, questions about your statement, alternatives, should payment difficulties arise, and with issues related to long-term educational or short-term emergency loans.



Financial Aid

Fellowships, Traineeships, and Scholarships

MIT makes available financial support to graduate students from a variety of sources and in several different forms — fellowships, scholarships, traineeships, teaching and research assistantships, the Federal College Work-Study Program, and the Technology Loan Fund. Many forms of support are granted solely on the basis of merit, while others are granted on the basis of financial need or a combination of merit and need.

Neither a department nor the Institute itself has the financial resources to provide support for all deserving students. Thus, it is important that prospective students explore all sources of aid available outside MIT to find means of financing their graduate programs.

Information on fellowships and other financial aid resources is available from departments and the Office of the Dean of the Graduate School, Room 3-138. Information on loans and the College Work-Study Program is available from the Student Financial Aid Office, Room 5-119.



At MIT, fellowships (and/or traineeships) differ from scholarships. A fellowship award to a graduate student covers tuition, partially or fully, and in addition provides a stipend to help defray living expenses. A scholarship, in the Graduate School context, covers all or part of tuition only. Most awards are made on the basis of academic merit; in some instances, financial need is a factor, but in any case, the recipient must be enrolled as a regular resident student.

Insofar as fellowships, scholarships, and research and teaching assistantships are provided for tuition payments, these funds are nontaxable.

Where fellowships are less than tuition, and where an accompanying stipend exists, a portion of the stipend may be applied against the remaining tuition, and that portion excluded from taxable income, always provided that the terms of the fellowship do not preclude this. Expenses for books, supplies, and equipment required for courses may also be excluded from taxable income.

Stipends accompanying teaching assistantships, on the other hand, are taxable regardless of the amount of nontaxable tuition provided.

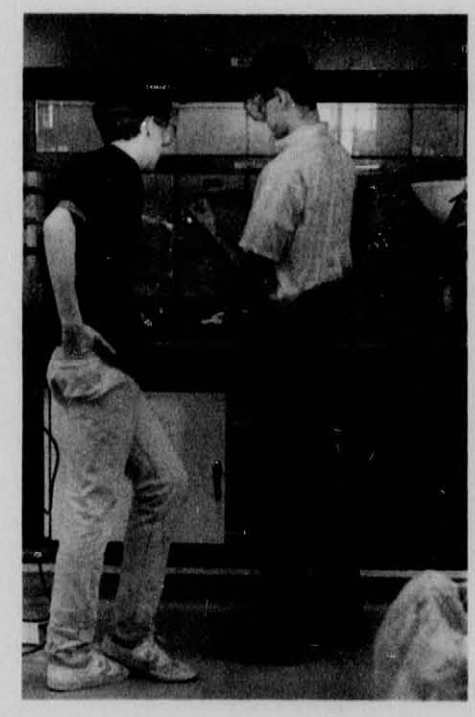
The Institute annually receives funds from individual and corporate donors for the support of fellowships and scholarships. In addition, government agencies and private foundations provide grants and fellowships — often directly to outstanding students for use at institutions of the student's choice. But occasionally these funds are directed to MIT for Institute designation of recipients.

Applicants to the Graduate School who seek financial support from any of the fellowships, traineeships, or scholarships administered by MIT, including those granted by national agencies and foundations for award by the Institute, should check the appropriate items on the regular Application for Admission to the Graduate School. Applicants will be considered for awards for which they are eligible after they have been accepted into a graduate program. Currently enrolled graduate students who seek financial support should consult with the appropriate departmental office.

Applications for fellowship aid for the academic year, beginning in June or September, must be filed by January 16. Applications for fellowship aid filed after this date are considered only if funds are available. Final action on applications is taken on the recommendation of departments to the Graduate School at the end of March, after the announcement of awards to applicants by the national agencies and foundations under their national competitive programs. A student who wins such a fellowship may be eligible for only a supplementary award in accordance with MIT's guidelines. For further information on these guidelines, please see the *Graduate School Manual*.

In accordance with a resolution of the Council of Graduate Schools in the United States, endorsed by most graduate schools in the US, a student has until April 15 to accept or decline an offer. If a student does not reply to an offer by this date, it may be canceled.

Every student holding a fellowship, traineeship, or scholarship for graduate study at the Institute must register as a full-time regular graduate student for the period of the award. If a student withdraws from the Institute before tenure expires, the award must be relinquished, and the student will be required to refund any sum already paid to the extent that the Dean of the Graduate School deems appropriate.



Teaching and Research Assistantships

MIT employs about 600 graduate students each year as part-time instructors or teaching assistants to aid the faculty in grading undergraduate quizzes, instructing in the classroom and laboratory, and conducting tutorials.

The departments regard seriously the benefits of a teaching assistantship as a preparation for a career in university teaching, and the Institute offers a prize each year — the Goodwin Medal — for conspicuously effective teaching by a graduate student.

The units for which an instructor or teaching assistant may register as a student are determined by the department in light of the student's assistantship duties, program of study, and compensation.

Appointments to teaching assistantships are made upon recommendation of the head of a department. A student who wishes to be considered for a teaching appointment should write to the department. Only full-time graduate students who are candidates for advanced MIT degrees may be appointed.

Each year about 2,500 graduate students at MIT hold appointments as research assistants. The principal duty of a research assistant is to contribute to a program of departmental or interdepartmental research.

Most students welcome the opportunity to participate as junior colleagues of the faculty in an ongoing research project that frequently influences their choice of thesis topic. Appointments to research assistantships are made by the department head to full-time students who are candidates for advanced MIT degrees.

The units for which a research assistant may register are determined by the department in light of duties and program of study. Research assistants are compensated on the basis of time devoted to their research. In all cases they must pay full tuition.

Teaching and research assistants receive stipends for the services that they provide; these stipends are taxable income that is subject to withholding. Teaching and research assistants also receive a nontaxable tuition scholarship.

Students who receive financial support from other sources (fellowships, scholarships, etc.) may receive supplementary stipends as teaching or research assistants in accordance with Institute and departmental guidelines.

Loan Funds

A graduate student's first recourse for loan assistance should be a Guaranteed Student Loan (GSL). To establish one's eligibility for this need-based loan, it is necessary to file 1) a Financial Aid Form (FAF) through the College Scholarship Service and 2) the MIT Graduate Loan Application. The maximum loan per year is $7,500, and interest for first-time GSL borrowers is 8% increasing to 10% in the fifth year of repayment. Massachusetts banks will lend to residents of any state. Generally, students should apply for GSCs with lenders from whom they have already taken GSLs. Where a student qualifies for the maximum loan, MIT, as an authorized lender under the Massachusetts GSL program, can make the loan. Application forms and details of the GSL application procedure may be obtained at the Student Financial Aid Office, Room 5-119.

For need remaining after a maximum GSL has been obtained, non-Federal MIT loans from the Technology Loan Fund are available. In determining need for this program, as well as the GSL program, MIT compares student resources available including assets, using appropriate student budgets. Need is determined within limits based on those budgets. Technology loans bear 9% interest and require a cosigner.

Other loans are available through outside agencies that are not based upon a formal need analysis. An example of this type of loan is the Supplementary Loans for Students Program (SLS), a Federally connected loan that is handled through banks. (This program was formerly called the PLUS/ALAS programs.) Although MIT is not an SLS lender, the Student Financial Aid Office in Room 5-119 can provide information about this and other similar financing plans.

International Students

Students who are not US citizens or who do not possess a permanent resident visa are not eligible for Federal loans, **nor are they eligible for MIT loans during their first year at MIT.** International students must be prepared to meet their expenses for the first year without recourse to loans from the Institute. Continuing international students should have a reasonable plan to meet expenses at MIT, which must not be limited to MIT loans. **All loans will require a cosigner who is a citizen or permanent resident of the US or Canada.**

Other Employment Opportunities

Employment is available both on or off campus. The Student Employment Office, Room 5-119, keeps up-to-date listings of job opportunities which are open to graduate students. Some positions are available directly through the academic departments, laboratories, and administrative offices on campus. Graduate students who hold full-time research or teaching assistantships or who receive full support on fellowships or traineeships are not usually eligible for such employment. The Office of the Dean of the Graduate School should be consulted for approval before undertaking such employment.

International students may work on campus, but may require special permission from the US government to work off campus. Citizens of other countries should consult the Dean for Student Affairs international student advisor before accepting employment.

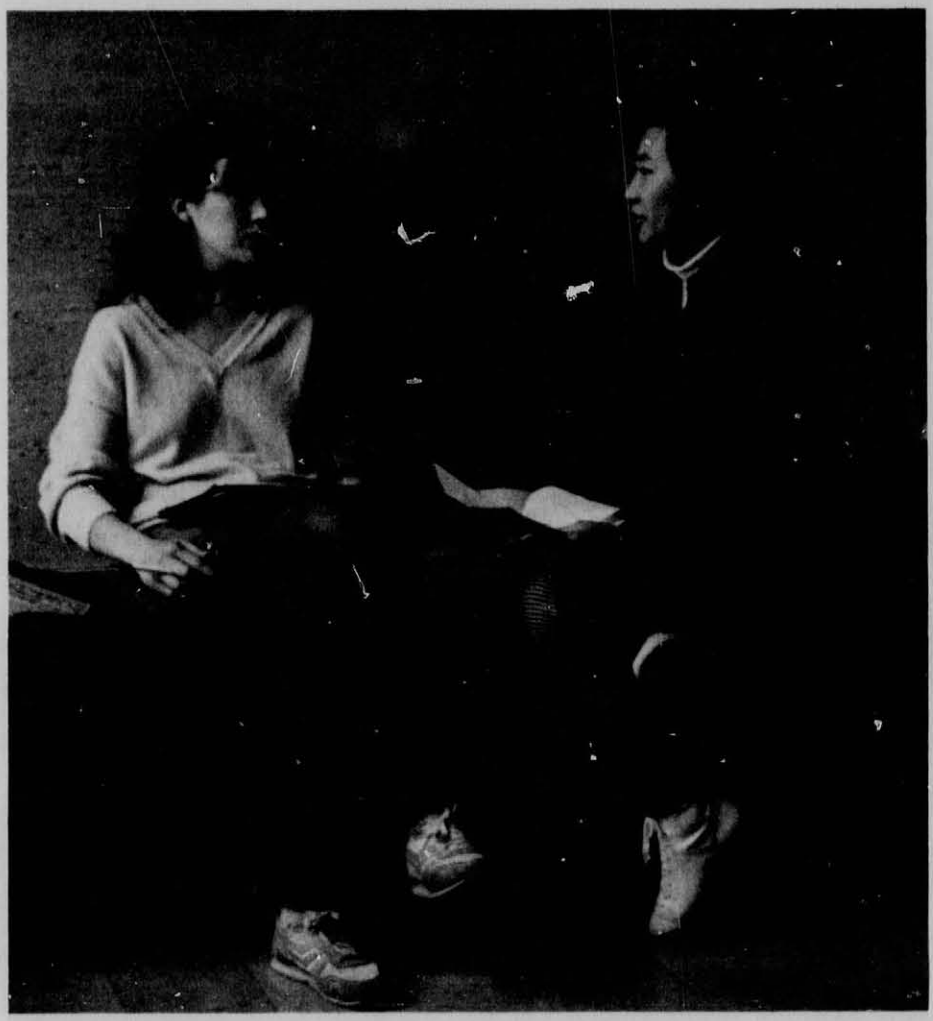
Graduate Residents

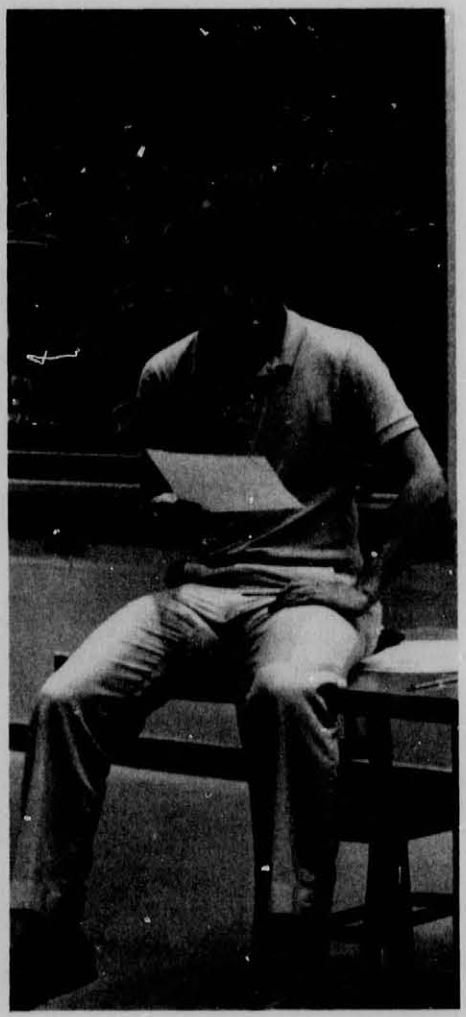
Regular resident graduate students who have completed at least one graduate year at MIT or new students who have been MIT undergraduates may apply to the Dean for Student Affairs for positions as Graduate Residents. Such positions provide room and board but no stipend.



V Academic Procedures and Institute Regulations







Academic Procedures

Registration

Complete information on registration procedures may be found in the "MIT Registration Instructions," available each term to continuing students in December and May in the Building 10 Lobby. After this time, the packet is available in the Registrar's Office, Room E19-335. Additional details may be found in the *Guide for Undergraduates and Faculty Advisors* and the *Graduate School Manual*.

Procedure for Retention of Student Status at MIT

Once admitted (or readmitted) to MIT, a person becomes a student at the start of the term for which he or she was admitted. Regular student status is retained until graduation, unless the student withdraws or is disqualified. For the fall and spring terms, **undergraduate** and **graduate** students must complete the following steps in order to continue student status during that term:

1) registration material issued by the Registrar must be completed and returned according to instructions; 2) all Institute charges must be paid when due, or satisfactory alternative arrangements must be made with the Bursar; 3) registration forms must be approved by the student's faculty advisor or registration officer; and 4) the ID validation sticker must be picked up by the student according to instructions.

If a student has begun the registration process but wishes to withdraw, he or she must notify the Office of the Dean for Student Affairs if an undergraduate, or his or her registration officer, if a graduate student.

A person wishing to be reinstated as an undergraduate must apply for readmission through the Office of the Dean for Student Affairs. A person wishing to be reinstated as a graduate student must apply for readmission through the Admissions Office and the student's registration officer.

People on campus who are not registered during a term are not considered students and have no student privileges.

Undergraduate and graduate students registered in the spring term retain their student status throughout the following summer, whether or not they register for the summer session, and cease being students if they do not register in the fall. Note, however, that graduate students making progress toward a degree during the summer must register for the summer session in accordance with the Graduate School regulations.

Registration Procedures

All students register for their subjects on Registration Day at the beginning of each term. New graduate students should pick up fall-term registration material during the summer in the Registrar's Office, E19-335.

All students at MIT are assigned an advisor. Advisors to freshmen are MIT faculty and staff, assigned at the beginning of the freshman year. (Freshmen may change advisors through the Undergraduate Academic Support Office, Room 7-104.) **Upperclass undergraduates** who have declared a major will be assigned a departmental advisor. Each **graduate** student is assigned to a faculty member in his or her department who also serves as the student's registration officer. Each student's program must be approved by his or her advisor, and changes may be made only with the advisor's approval.

All subjects to be taken during the current term, including thesis, cross-registration with Wellesley or Harvard, and ROTC, should be listed on the Registration Form. The units for independent study and thesis subjects should be indicated. The units for thesis are listed as laboratory units.

A third- or fourth-year undergraduate student who wants to take an elective subject Pass/Fail using the Junior-Senior Pass/Fail option should be sure to indicate P/F beside the subject on the Registration Form. The faculty advisor and student should be sure that the subject to be designated Pass/Fail is not being used to fulfill either a department or an Institute requirement, and that the student does not take more than a total of two subjects under this option during his or her junior and senior year. The Pass/Fail option is not available to graduate students.

Correction Cards signed by the student's faculty advisor for undergraduates and registration officer for graduate students should be used for all changes in registration after Registration Day. The specific deadlines for such changes are listed in the academic calendar, found in Chapter I of this catalogue. The instructor's signature is also required if a subject is added after the first week of the term.All Correction Cards should be hand delivered by the student to the Registrar's Office, Room E19-335, or to the Undergraduate Academic Support Office, Room 7-104.

The Registrar's Office sends out a "Status of Registration Form" to every student during the fourth week of the term. Additional Status Forms are sent out at three-week intervals to every student for whom the Registrar has received a Correction Card since the previous set of Status Forms was issued. On these forms will be listed the student's program as it is recorded in the Registrar's Office. This will confirm the student's registration and help identify any discrepancies. If the Registrar's Office has received no change in the student's record, then no further Status Forms are generated after the fourth week of the term.

The Institute holds each student fully responsible for checking the accuracy of his or her initial Registration Form and any subsequent Correction Cards submitted to the Registrar's Office, for ensuring that the Registrar is provided with a correct current mailing address, and for carefully reviewing each Status of Registration Form generated by the Registrar to make sure that it accurately reflects his or her registration. Steps to eliminate any discrepancies should be taken promptly by the student. The student should keep copies of the original Registration Form and all subsequent Correction Cards and Status of Registration Forms as evidence of having followed these procedures.

If an **undergraduate** wishes to add or drop a subject or to make or change a Pass/Fail designation after the deadline dates, the student must petition the Committee on Academic Performance (CAP), Room 7-103. **Graduate** students must petition the Office of the Dean of the Graduate School. Such petitions are not automatically approved.

An **undergraduate** student who wishes to withdraw during a term or arrange for a leave of absence must see a dean in the Student Assistance Services Section of the Dean's Office, Room 5-106. **Graduate** students should consult their department graduate offices or the Office of the Dean of the Graduate School.

Subject Credits and Designations

The credit hours (units) for each subject indicates the number of hours spent each week in class and laboratory, plus the estimated time that the average student spends each week in outside preparation, for one regular term. Each subject is listed with three credit numbers, showing in sequence the units allotted to: class; laboratory, design, or fieldwork; and preparation. Each unit represents about 14 hours of work per term. The total unit credit for a subject is obtained by adding together all the units shown. The units for each subject are indicated in the subject descriptions listed in Chapter VIII. Additional information regarding subject designations may be found at the beginning of Chapter VIII on the page titled "Explanatory Notes."

The typical **undergraduate** student load, based on a four-year program, is 45 to 48 units per term. However, if approved by his or her faculty advisor, a student may follow a program leading to an S.B. degree in either more or less than eight terms.

Academic Performance and Grades

Light-Load Registration by Undergraduates

The Institute feels that the concept of a four-year residential college, requiring a full-time academic program, is central to the MIT undergraduate experience. An MIT degree represents not only a specified number of credit units and a collection of subjects, but an intensity and continuity of involvement in an academic enterprise and an immersion in the culture of MIT as well. In general, therefore, MIT is not an appropriate place for pursuing an undergraduate education on an extended, part-time basis.

Requests from students for light-load registration status are handled under the following policy: Once enrolled as a regular student, an undergraduate may not carry a light load of subjects (register for fewer than 32 units) for more than a total of two terms without petitioning the Committee on Academic Performance (CAP). The CAP allows use of the light load beyond a second term only for very special circumstances. Arrangements to take a reduced load of subjects should be initiated prior to the beginning of the term. The procedure to be followed in this regard is described in the *Guide for Undergraduates and Faculty Advisors*.

Advanced Standing Examinations for Undergraduates

To qualify for an Advanced Standing Examination, an undergraduate student must never have been registered for or attended class in the subject concerned. A freshman who takes such an exam shall receive the grade of P for passing performance, but no record will be kept of failing performance. For all other students, a grade ranging from A to F as usual will be recorded on the transcript. Any passing grade entitles a student to full credit for the subject. For freshmen, such credit will count toward the 60- or 63-unit credit limit unless the exam is taken either in the September or February examination period (see Credit Limit for Freshmen in Chapter III).

Grade Reports and Transcripts

Grade reports are issued by the Registrar at the end of each term and summer session to all registered students. Students may order transcripts of their academic record at the Registrar's Office, Room E19-335, upon presentation of a receipt from the Cashier's Office, Room 10-180, at a cost currently set at $2 per copy.

Final Examinations

Final examinations are held at the end of each term; the schedule is issued about two months before the examination period. Each student is held responsible for 1) obtaining an examination schedule at the Information Center, Room 7-121; 2) reporting any conflicts in examinations to the Schedules Office, Room E19-338, in the Office of the Registrar before the time limit given on the examination schedule; and 3) attending the final examinations required in the subjects for which he or she is registered.

No member of the instructing staff can excuse a student from a scheduled final examination. Absence from any final examination is equivalent to a failing grade except on presentation of adequate evidence of sickness or other valid reason for the absence. The Dean for Student Affairs (for undergraduates) or the Dean of the Graduate School (for graduate students) may permit a student whose term work has been satisfactory to take the next scheduled examination on the subject. The instructor may, if the evidence warrants, issue a final grade without requiring a postponed final examination.

Undergraduate Academic Standards

It is the responsibility of the Committee on Academic Performance (CAP) to see that minimum academic standards proposed by the individual departments are consistent throughout the Institute for undergraduates and conform with the rules and regulations approved by the faculty. In view of the individual nature of student academic performance, it is impossible for the CAP to set forth rigid standards of academic performance to be used throughout the Institute. The Institute generally expects undergraduate students to complete the requirements for a single S.B. degree in four years; this establishes a normal load of subjects at approximately 45 units of credit per term. Normally, however, the CAP accepts a minimum academic record of at least 36 units of credit with a term rating of 3.0 or above on a 5.0 scale at the end of any regular term, unless the Committee has specifically notified an individual student that a higher level of performance is required. (The latter would only occur as a result of previously poor performance.)

In cases where these criteria are not met, the CAP considers the academic performance of each student on an individual basis. Consideration is given not only to the grades received in the various subjects for which the student is registered, but also to the total number of subject units, the nature of the subjects themselves, and all those factors in the student's own personal situation that may have affected his or her academic performance in a given term. More detailed information concerning the procedures followed by the CAP at the end of term in reviewing the academic records of undergraduate students is given in the *Guide for Undergraduates and Faculty Advisors*. This booklet is published by the CAP approximately every four years. Copies are mailed to all sophomores and undergraduate faculty advisors by the Committee at the time of publication, and additional copies may be obtained from the CAP office, Room 7-104, (617) 253-4164.

For Title IV purposes, an undergraduate student is considered to be making satisfactory progress as long as at least 33 units per term have been completed with a term rating above 3.0 at the end of any regular term. All undergraduates whose performance falls below this standard will be considered, for Title IV purposes, to be under CAP review during the subsequent term. A student will be considered to be making satisfactory progress if the CAP does not withdraw permission for the student to continue.

Graduate Academic Standards

It is the responsibility of the Committee on Graduate School Policy (CGSP) to monitor minimum academic standards for graduate students and special graduate students in accordance with the rules and regulations of the faculty. The CGSP reviews the academic records of all graduate students at the end of each term (including the summer session), and students with cumulative ratings of 3.5 to 4.0 are given particular attention. Consideration is given not only to low grades, but to other factors affecting a student's performance in meeting the requirements for the degree program in which he or she is enrolled.

Recommendations for action by the CGSP are made by departmental graduate committees. Unless extenuating circumstances are found, students who are not making satisfactory progress towards a degree may be denied permissions to continue or may be warned that without substantial improvement the following term, they may be refused further registration in the Graduate School.

More detailed information concerning procedures followed by CGSP may be found in the *Graduate School Manual*. It is also important for students to be informed of individual department requirements and expectations concerning academic performance.

For Title IV purposes, a graduate student is considered to be making satisfactory progress as long as his or her cumulative grade point average exceeds 4.0, and if the number of terms of enrollment does not exceed five for an S.M. candidate or 10 for a Ph.D. or Sc.D. candidate. Graduate students whose performance falls below this standard will be considered, for Title IV purposes, to be under CGSP review during the subsequent term. A student under CGSP review will be considered to be making satisfactory progress if the CGSP does not withdraw permission for the student to continue.

Grades

The grades to be used for undergraduate and graduate students who satisfactorily complete the work of a subject by the end of the term are:

A
Exceptionally good performance, demonstrating a superior understanding of the subject matter, a foundations of extensive knowledge, and a skillful use of concepts and/or materials.
B
Good performance, demonstrating capacity to use the appropriate concepts, a good understanding of the subject matter, and an ability to handle the problems and materials encountered in the subject.
C
Adequate performance, demonstrating an adequate understanding of the subject matter, an ability to handle relatively simple problems, and adequate preparation for moving on to more advanced work in the field.
D
Minimally acceptable performance, demonstrating at least partial familiarity with the subject matter and some capacity to deal with relatively simple problems, but also demonstrating deficiencies serious enough to make it inadvisable to proceed further in the field without additional work. [Note: Some departments may require students with D-level performance in certain prerequisite subjects within the departmental program to do additional work before proceeding with the follow-on subject, which could include retaking the prerequisite.]
P
When the use of the single passing grade P is authorized, it may reflect performance at any of the levels, A, B, C, D.

The following notations are used by the Registrar for satisfactory completion of work in circumstances indicated:

S, notation for credit awarded for work done elsewhere.

SA, notations for satisfactorily complete doctoral thesis. Doctoral theses are not graded.

The grades and notations to be used for subjects not passed or not completed are:

F, failed. This grade also signifies that the student must repeat the subject to receive credit.

O, absent. This grade indicates that the student was progressing satisfactorily during the term but was absent from the final examination or absent during the last two weeks of the term, or both. An O grade carries no credit for the subject. Unsatisfactory performance because of absence throughout the term should be recorded as F.

OX, absence satisfactorily explained to and excused by the Dean for Student Affairs in the case of an undergraduate student or by the Dean of the Graduate School in the case of a graduate student. The faculty member in charge of the subject will be notified when an O is changed to an OX. An OX carries no credit for the subject. However, the faculty member in charge must provide the student the opportunity to receive a credit-carrying grade. This may be done with or without the instructor requiring a postponed final examination or other additional evaluation procedure.

DR, a notation to be used only on the student's internal record for a subject dropped after the fifth week of the regular term.

I, incomplete. The grade of I indicates that a minor part of the subject requirements has not been fulfilled and that a passing grade is to be expected when the work is completed. The grade I for the term remains permanently on the student's record even if/when the course is completed. A typical example of a "minor portion of the work required" might be a paper or a laboratory report. The work is to be completed before the end of the fifth week of the succeeding term of the regular academic year, but the deadline may be extended with explicit approval of the faculty member in charge. Graduate students must petition the Office of the Dean of the Graduate School to record a grade after a deadline. For undergraduate students, if the work is not completed before the end of that term (with the exception noted below), the I grade will be changed to the notation R on the internal grade report and the student must register for and repeat the subject in order to receive credit. When completion of the subject requires resources which are normally but not continuously available, this must be indicated on the form reporting the I grade and the work must be completed in the earliest term in which the resources are available.

J, a notation assigned for work such as thesis, UROP, or "At Plant" registration (internship or industrial practice), which has progressed satisfactorily, but has not been completed. Grade given upon completion of the work in a later term also covers this term. Faculty members and instructors must obtain approval from, the Committee on Curricula to use the grade of J in subjects other that those mentioned above.

U, a notation for thesis work that has not been completed and in which progress has been unsatisfactory. Grade given upon completion of the work in a later term also covers this term. Unless a student's progress improves significantly, the student may expect that grade to be failing.

T, temporary notation. It is used for subjects which cover the equivalent of one term's work, but are scheduled over parts of two normal grading periods. Prior approval must have been obtained from the Committee on Curricula for undergraduate subjects or the Committee on Graduate School Policy for graduate subjects. This notation is recorded only on the student's internal record. A permanent grade must be assigned when the subject is finished.

End-Of-Term Regulations

The Faculty Regulations governing end-of-term examinations and assignments, together with the Faculty Policy Committee's interpretation, are the following, and apply to both undergraduate and graduate subjects:

• Major assignments should be assigned early enough to allow students the opportunity to manage their time effectively throughout the term. Instructors are asked to provide, during the first three weeks of classes, a clear and complete description of the requirements in each subject, including the due dates for required work and the schedule of examinations during the term.

• Final examinations are held during the final examination period following each term, and must be scheduled through the Office of the Registrar, as well as announced to the class, before the end of the third week of the term. The final examination scheduled in any subject can last from one hour to three hours.

• For each subject that has a **final exam**, no examination may be given and no assignment may fall due during the last week of classes.

• Each subject in which **no final exam** is given may have at most **one** of the following during the last week of classes: either a one-hour quiz may be given during a regularly scheduled class period or one assignment (term paper, lab report, take-home exam, problem set, oral presentation, etc.) may fall due. (A quiz of one and one-half hours is allowed, but only if done within a regular class period.)

• It is inappropriate for comprehensive examinations (exams covering most of the term's work) to be given at any time other than during the final exam period.

• No classes, examinations, or exercises of any kind may be scheduled beyond the end of the last regularly scheduled class in a subject, except for final exams scheduled through the Registrar's Office. Any formal reviews of subjects should be held during regular class periods, but the rule does not exclude the possibility of sessions after the last day of classes at which the instructing staff is available to answer questions of students who choose to attend. (The Architecture design reviews that occur during finals week are considered to be equivalent to final examinations and are scheduled by the Department.)

• No assignment of any kind may be given that falls due after the last regularly scheduled meeting of the class for that subjects. This does not prevent an instructor from giving an extension to an individual student, but an extension should not need to be given to the majority of the class.

• Any departure from these rules requires permission of the CAP for undergraduate subjects or the CGSP for graduate subjects — and that any such approved exception will be announced early in the term and emphasized appropriately. Asking students to vote on some deviation from the rules is not an acceptable procedure.

Faculty or students with questions regarding the interpretation or application of any of these provisions should contact the Chairman of the Faculty or request the assistance of the CAP, Room 7-103, 253-4164.

Institute Regulations

Policies and Procedures

MIT assumes that all students come to the Institute for a serious purpose and expects them to be responsible individuals who demand of themselves high standards of honesty and personal conduct. Disappointments in this expectation have been rare. Therefore, it is MIT's policy to have as few rules and regulations as are consistent with efficient administration and general welfare.

Fundamental to the principle of independent learning and professional growth is the requirement of honesty and integrity in conduct of one's academic and nonacademic life. Maintenance of a healthy living and learning environment requires that all members of the community exercise due respect for the basic rights of one another.

Academic Honesty

Cheating, plagiarism, unauthorized collaboration, and other forms of academic dishonesty are considered serious offenses for which disciplinary penalties can be imposed.

Some academic offenses by students can be handled directly between the faculty member and the students involved. In some cases, it may be necessary for the department head to review or otherwise to assist in, the resolution of the matter. When a dispute cannot be resolved satisfactorily within the department, a complaint against a student can be brought to the Committee on Discipline, as explained in the section on Complaint and Disciplinary Procedures.

Institute Policy on Student Absence and Religious Beliefs

Massachusetts state law regarding student absence due to religious beliefs has been adopted by the Institute as follows:

Any student who is unable to attend classes or participate in any examination, study, or work requirement on a particular day because of his or her religious beliefs is excused from any such activity. The student will be given the opportunity to make up the work that was missed, provided that the makeup work does not create an unreasonable burden upon MIT.

The Institute will not levy fees or charges of any kind when allowing the student to make up missed work. In addition, no adverse or prejudicial effects will result to students because they have made use of these provisions.

Institute Policy on Racist Behavior

Racist behavior, whether subtle or blatant, is unacceptable at MIT. It will be addressed with quick and decisive action whenever it occurs. Racism and racist behavior interfere with an individual's growth and well-being in the academic and living environments at MIT.

The Institute is serious about the elimination of racism and is committed to a confidential and thorough handling of any allegation of racist behavior. In such situations, it will be the Institute's aim to protect the rights of all individuals involved and to safeguard the welfare of everyone in the MIT community.

Any member of the MIT community who believes that he or she has encountered racist behavior is encouraged to raise the issue, or lodge a complaint, in accordance with established grievance procedures. Additional information on procedures for following up on concerns regarding racism and racist behavior is available from the Office of the Dean for Student Affairs, including a brochure entitled *You Can Make a Difference* that outlines parallel routes within the Institute for addressing racist behavior.

Additional information on conduct and discipline may be found in the position paper by the Committee on Discipline entitled "Infractions of the MIT Code and Violations of the Law," which is available from the Office of the Dean for Student Affairs.

Institute Policy on Harassment

Harassment of any kind is unacceptable at MIT and is in conflict with the policies and interests of the Institute. Moreover, many forms of harassment have been recognized by the US Equal Opportunity Commission and the courts as violations of the civil rights laws.

Harassment is defined as verbal or physical conduct that has the intent or effect of unreasonably interfering with any individual's or group's educational and/or work performance at MIT, or creating an intimidating, hostile, or offensive educational and work environment on or off campus. Harassment on the basis or race, color, sex, religion, handicap, national origin, or sexual orientation includes harassment of an individual in terms of a stereotyped group characteristic, or because of that person's identification with a particular group. With reference to sexual harassment, the definition also includes unwelcomed sexual advances and requests for sexual favors which might be perceived as explicitly or implicitly affecting educational or employment decisions concerning an individual.

Any member of the MIT community who believes that he or she has been harassed is encouraged to raise the issue, or lodge a complaint, in accordance with established grievance procedures. Additional information on procedures for following up on harassment concerns is available from the Office of the Dean for Student Affairs, including a brochure entitled *Tell Someone*, that outlines parallel routes for addressing harassment concerns.

Additional information on conduct and discipline may be found in the position paper by the Committee on Discipline entitled "Infractions of the MIT Code and Violations of Law," which is available from the Office of the Dean for Student Affairs.

Institute Policy on Hazing

In accordance with Massachusetts state law (Chapter 536), the Institute has adopted the following policy statement on the crime of hazing:

The term **hazing** is defined by law as "any conduct or method of initiation into any student organization, whether on public or private property, which willfully or recklessly endangers the physical or mental health of any student or other person." Such conduct includes but is not limited to beating; whipping; branding; forced calisthenics; exposure to the weather; forced consumption of any food, liquor, beverage, drug or other substance; or any other brutal treatment or forced physical activity that may affect the physical health or safety of the person.

According to the law, anyone identified as the principal organizer as well as any participant in the crime shall be punished by a fine of not more that $1,000 or by imprisonment for not more than 100 days, or both.

Any person witnessing a hazing incident must report the incident to the MIT Campus Police. Failure to make such a report is punishable by a fine of not more than $500.

All registered students should receive a copy of the law from the Office of the Dean for Student Affairs at the time of fall registration and are required to sign an acknowledgment stating they have received a copy. Anyone desiring a copy of the law should contact the Dean's Office.

MIT considers acts of hazing to be extremely serious offenses to the community and will treat offenders accordingly. The MIT Interfraternity Conference has also developed its own policy on hazing, which is applicable to all fraternities, sororities, and independent living groups.

Policy Statement on the Use of Alcohol

MIT supports the observance of all laws and regulations governing the sale, purchase, and serving of alcoholic beverages by all members of its community and expects that these laws will be adhered to at all events associated with the Institute. This includes activities on the MIT campus, in MIT-approved independent living groups, and at off-campus functions sponsored or supported by MIT or any of its affiliated groups. A reference guide to existing state laws is available from the Office of the Dean for Student Affairs.

The Institute strongly encourages all faculty, staff, and students to become familiar with these laws and to consider the associated penalties and other potential risks that can result from violations.

Included in these laws are those that govern driving under the influence of alcohol, the purchase of alcohol by and for persons under the legal drinking age, and the serving of alcohol to persons who are either under age or intoxicated. It should be noted that the drinking age in Massachusetts was raised to 21 on June 1, 1985.

The Institute does not intend through its guidelines or policies to restrict the responsible use of alcohol by members of the MIT community who are of the legal drinking age in Massachusetts, or older. However, efforts to observe existing laws and regulations in an environment in which the majority of the undergraduate student body will not be of drinking age will almost certainly impose some constraints upon those who are of age.

A more detailed policy statement on the use of alcohol, including the Institute's Residence/Orientation alcohol policy, is available in the Office of the Dean for Student Affairs.

Other Personal Conduct

All members of the MIT community are expected to conduct themselves with proper respect for one another and for each other's property.

Improper use of Institute property or facilities, including keys, computers, telephones, and so forth, or misuse of MIT's name, or violation of Institute regulations, may result in disciplinary proceedings within the Institute, or legal proceedings outside of MIT, or both.

Off-campus misconduct is not a basis for MIT action unless the Institute considers such misconduct to be in violation of the educational mission of the Institute or to be a clear and present danger to Institute functions. The Institute reserves the right to determine its jurisdiction on a case-by-case basis. Student status in no sense renders an individual student immune from the jurisdiction of civil or criminal courts and other government authorities. All MIT actions must conform with applicable law.

MIT handles internally some incidents that might give rise to civil or criminal liability. This is done with the understanding by the outside community that MIT deals seriously with such offenses. As is the case for many universities local authorities often rely on MIT to resolve such issues as long as the internal policies and procedures are effective and adequate. MIT action by itself, however, does not preclude the possibility of other judicial remedy.

If an infraction causes a student to be involved both in Institute disciplinary proceedings and in criminal proceedings, and if an Institute decision might prejudice the court case, the Institute will usually hold its decision in abeyance until after the criminal proceedings have been concluded.

MIT traditionally has placed considerable responsibility on students governing groups to deal with problems in the student community, e.g., the Dormitory Council and the Interfraternity Conference. Nearly all Institute houses and independent residences have judicial procedures that deal with disputes and violations of rules and regulations occurring in their living groups.

Problems and disputes that cannot be resolved at the local level are referred to the Office of the Dean for Student Affairs for advice, guidance, or resolution. In appropriate cases, the Dean may place the student on disciplinary warning or probation or may prohibit a student from living in an Institute residence.

Complaint and Disciplinary Procedures

Students who believe that they have been treated improperly for any reason are encouraged to raise their concerns. Difficulties with other students should be pursued within the living group or department when appropriate, or else brought to the Committee on Discipline. Concerns relating to academic or work situations should be raised directly with professors, instructors, academic advisors, and immediate work supervisors — as appropriate to the nature of the problem.

If a problem cannot be resolved at this level, students should either seek assistance from their department head or dean or avail themselves of the assistance of the Office of the Dean for Student Affairs or the Office of the Dean of the Graduate School. In situations where a student feels wrongly accused and unjustly penalized, the student may request advice and assistance from the Office of the Dean for Student Affairs regarding the possibility of further discussion among the parties or referral of the case to the Committee on Discipline. Students may also bring concerns to the attention of either of the two Special Assistants to the President.

It is Institute policy that individuals will not be reprimanded or discriminated against for initiating an inquiry or complaint and that the rights of the individual against whom a complaint is made will be protected.

Anyone in the MIT community — including individual students, faculty members, and employees of the Institute — may bring a complaint against a student to the Committee on Discipline. The Committee is composed of six faculty members, five students, and the Dean for Students Affairs, *ex officio*. It adjudicates cases of academic offenses, violations of Institute regulations and standards, and other infractions alleged to have been committed by students.

A complaint against a student must be submitted in writing to the Office of the Dean for Student Affairs or to the Chairperson of the Committee on Discipline. There are procedures to protect the rights of a student, including assistance in preparing a defense. The student who has been charged may select an advisor from the MIT community to assist him or her in preparing a response to the charge(s) and to attend the Committee hearing with the student; the person making the charge has the same rights. Statements at a Committee hearing are made by the person who brought the charge, by the student who is charged (if he or she chooses to speak), and by witnesses. Detailed procedures of the Committee on Discipline are given in the "Statement of Discipline Committee Procedures," which is available from the Office of the Dean for Student Affairs. Among the sanctions available to the Committee are reprimand, informal probation, formal probation with or without monitoring, and recommendation to the President that the student be suspended or expelled. Formal probation, suspension, and expulsion are noted on the student's transcript for a specified period. Such notation may be removed upon written application to the Committee under conditions set forth in the statement referenced earlier.

This procedure serves also as the grievance procedure for students as required by Title IX of the Federal Education Amendments of 1972 with regard to grievances arising out of alleged discrimination on the basis of sex, and for handicapped students alleging failure to comply with Sections 503 and 504 of the Rehabilitation Act of 1973. Inquiries concerning the Institute's policies and compliance with applicable laws, statutes, and regulations (such as Title IX and Section 504) may be directed to Dr. Clarence G. Williams, Special Assistant to the President and Assistant Equal Opportunity Officer, Room 3-221, (617)253-4556.

Additional information on conduct and discipline may be found in the position paper by the Committee on Discipline entitled "Infractions of the MIT Code and Violations of Law," available from the Office of the Dean for Student Affairs. A description of the grievance procedures for persons employed at MIT is included in *Policies and Procedures.*

Privacy of Student Records

The Family Educational Rights and Privacy Act of 1974 (sometimes called the "Buckley Amendment") gives students certain rights, consistent with the privacy of others, to review records, files, and data held about them on an official basis by the Institute, and also gives students a right to challenge the content of those records, files, and data that they believe are inaccurate, misleading, or otherwise in violation of their privacy and other rights. This Act also imposes certain controls on access to information about students.

Under the Act, "education records" means those records which are directly related to a student and are maintained by MIT. Education records at MIT include those that are kept by the offices of the Registrar, Admissions, Dean for Student Affairs, Dean of the Graduate School, Bursar, Student Financial Aid, UROP, academic departments and advisors, standing committees of the faculty, Alumni Association, and the Archives. Certain records are not included as education records under the Act. They include personal files held by Institute faculty and staff that are not accessible or revealed to others, certain records of the Campus Police, and medical records maintained by the Medical Department.

Review of Records and Challenges to Record Content

Subject to the exceptions stated below, all education records of the Institute that are identified with an individual student or former student will be available for review at the request of that individual. A student may make a request directly to the custodian of the record or to the Office of the Dean for Student Affairs. A student shall not be permitted to review those specific portions of his or her education record that refer to other identified students. Individuals may challenge the content of their education record with the custodian or through the Office of the Dean for Student Affairs. If a dispute remains pertaining to the accuracy or completeness of the record, the student shall be afforded a hearing.

Information about students assembled prior to January 1, 1975, under promises of confidentiality, explicit or implicit, will not be made available for review by the concerned students without the written consent of the author. A letter of recommendation that was placed in a student's education record after January 1, 1975, will not be made available to the student for review, if the student has previously waived his or her right to review that specific letter.

Under the Family Educational Rights and Privacy Act of 1974, an MIT student who has applied for admission to, but has not yet attended, another component unit of MIT (e.g., a graduate school or department) does not have the right to review his or her education record within that component unit unless and until the student begins to attend that unit. However, individual departments may choose to disclose such information to such a student.

Although medical records maintained by the Medical Department are not considered education records under the Family Educational Rights and Privacy Act of 1974, they are regulated by Massachusetts law relating to the rights of patients and residents of health facilities. Under this law, students have the right to confidentiality of their medical records as well as the right to inspect and to obtain a copy of these records.

Disclosure of Information about Students

Disclosure of information in education records to persons within or outside the Institute, except as indicated below, requires the student's written consent. The written consent must be signed and dated and must include a specification of the records to be disclosed, the purpose of the disclosure, and the party to whom the disclosure may be made. Upon request, the student shall be provided with a copy of a record that is disclosed pursuant to this consent. A record of each request and of each disclosure must be made part of the education records to which the student has access. Institute officials may have access, without the student's prior consent and without a record being made, to specific student records in which they have a legitimate educational interest. For this purpose, Institute officials include both academic and administrative personnel. Only those Institute officials acting in a capacity intended to further the educational interests of the student and possessing a clear need to obtain information about the student may have access to that information. For example, faculty advisors may have access to relevant education records of their advisees. In addition, custodians of students' educational records shall exercise responsibility to treat personal information with appropriate care and discretion and not exchange such information unnecessarily, and to ensure that the transfer of information between persons not in the same office or working group serves a legitimate Institute purpose. (Where such transfer is unusual, prior notice should be given to the individual and where practicable, permission should be obtained.)

Under the Family Educational Rights and Privacy Act, education records may be disclosed without a student's prior consent to officials of another educational institution in which the student seeks or intends to enroll, or in which the student is enrolled concurrently. In such cases, the student must be notified of the disclosure, provided with a copy of the disclosed records if he or she requests, and granted an opportunity for a hearing to challenge the contents of the disclosed records. All education records that are released to persons or organization outside of MIT must be released on the condition that they will be used only for their stated purpose and that no other party will have access to them without the student's written consent. The disclosed material should contain a statement to the effect that acceptance of these materials constitutes an agreement to abide by this condition.

Students who hold temporary, non-immigrant visas with F-1 classification are required by the US Immigration and Naturalization Service (INS), when applying for these visas, to authorize MIT to release to INS, upon its request, certain information and documents about themselves. A detailed description of the information subject to these requirements is available in the Office of the International Students' Advisor. It is MIT's policy to release such information only to the extent required by law.

Certain personally identifiable information from a student's education record, designated by the Institute as directory information, may be released without the student's prior consent and without a record being made. This information includes name, term and permanent addresses, term phone number, department, class, degrees received, dates of attendance, and, for an intercollegiate athletic team member, weight and height. A student has the right to withhold the designation of any or all of these categories of information on himself or herself as directory information. To exercise this right, a student should submit by the end of the second week of the fall term a request form available from the Registrar. Intercollegiate athletic team members who wish to withhold the designation of weight and height as directory information should contact the Sports Information Director in the Athletic Department. The *Student Directory*, although it contains most of the information listed above, is intended primarily for use by members of the MIT Community. Information in the *Directory* may be made available to persons outside of MIT only in response to inquiries about specified individuals. Providing the *Directory* or similar listings to persons outside MIT or using the *Directory* for non-Institute purposes is prohibited. Massachusetts law permits local municipalities to obtain census information, similar to directory information, pertaining to students living in MIT residences. In the case of court orders or subpoenas for information, the affected individual should be notified immediately and the release of such information should then be made only by an officer of the Institute who has been specifically authorized to do so.

Administration of Institute Policy

Questions concerning this policy may be directed to the Dean for Student Affairs; Chairman of the Committee on Privacy; or the Vice President in the Office of the President, who is the senior officer responsible for overseeing Institute operations with respect to the protection of individual privacy. Students who believe that their rights under the Act have been abridged by the Institute may file complaints with the FERPA Office, Department of Education, Washington, DC 20201.

Letters of Recommendation

A student's request for a letter of recommendation to be written by Institute faculty or staff constitutes a consent to disclosure and should, therefore, be made in writing.

A student or former student may voluntarily waive his or her right to review or receive copies of letters of recommendation or other documents sent to MIT or written by a member of the MIT faculty or staff in connection with admission to educational institutions, employment, or consideration for an honor or recognition. Such a waiver must be in writing and must include adequate identification of the concerned individual, the author of the letter, and the purpose for which the letter is intended. Such waivers must not be required as a condition for admission to, receipt of financial aid from, or receipt of any other services or benefits from any agency or institution. Faculty and staff should not encourage waivers unnecessarily.

Personal Files of Faculty and Staff

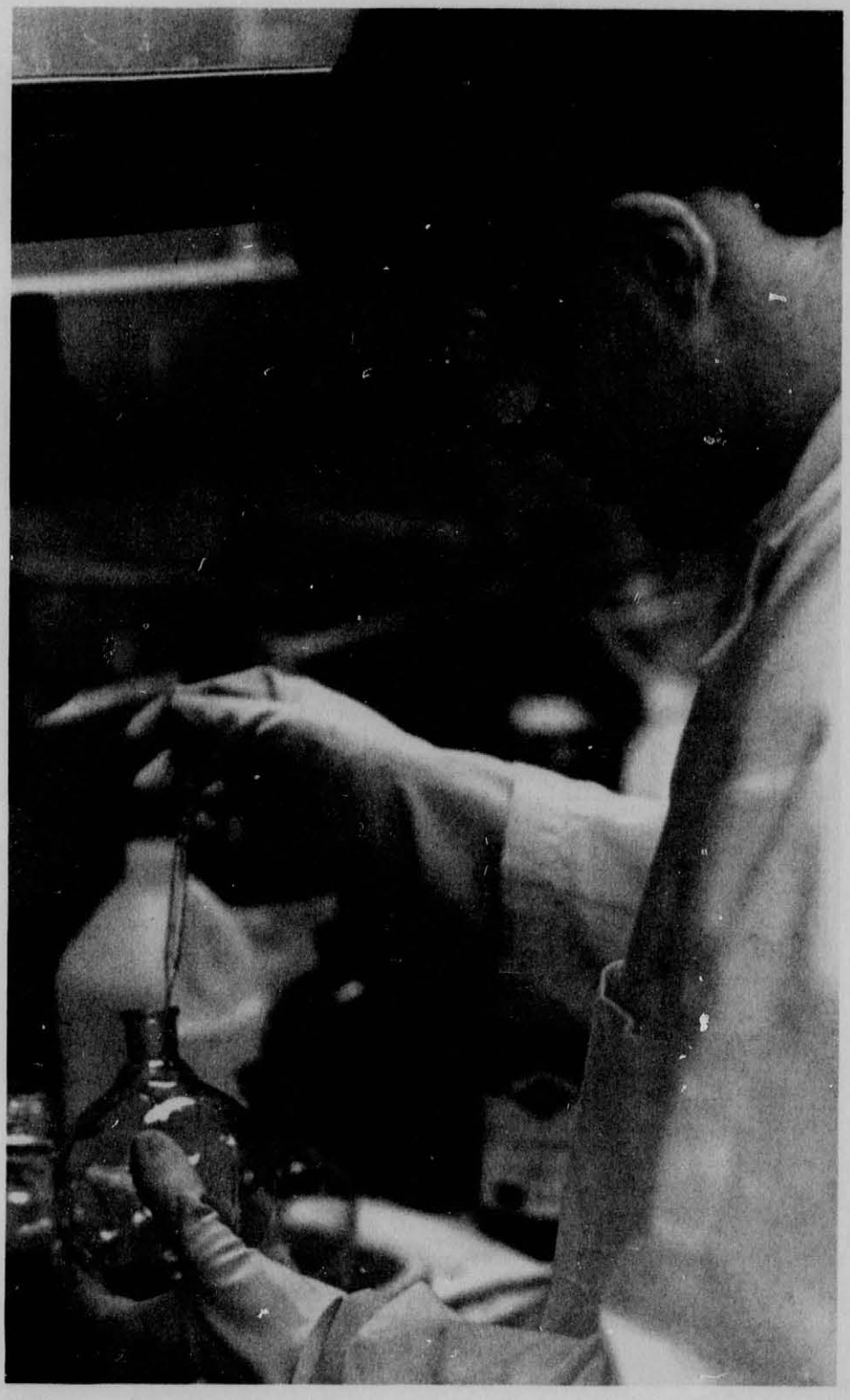
The personal files of members of the faculty and staff that concern students, including private correspondence and notes which refer to students, are not regarded as education records and are not per se subject to review by students. However, if the personal files are made available to others within the Institute or to parties outside MIT, then they are a part of a student's education records, and the student has a right to review those personal files.

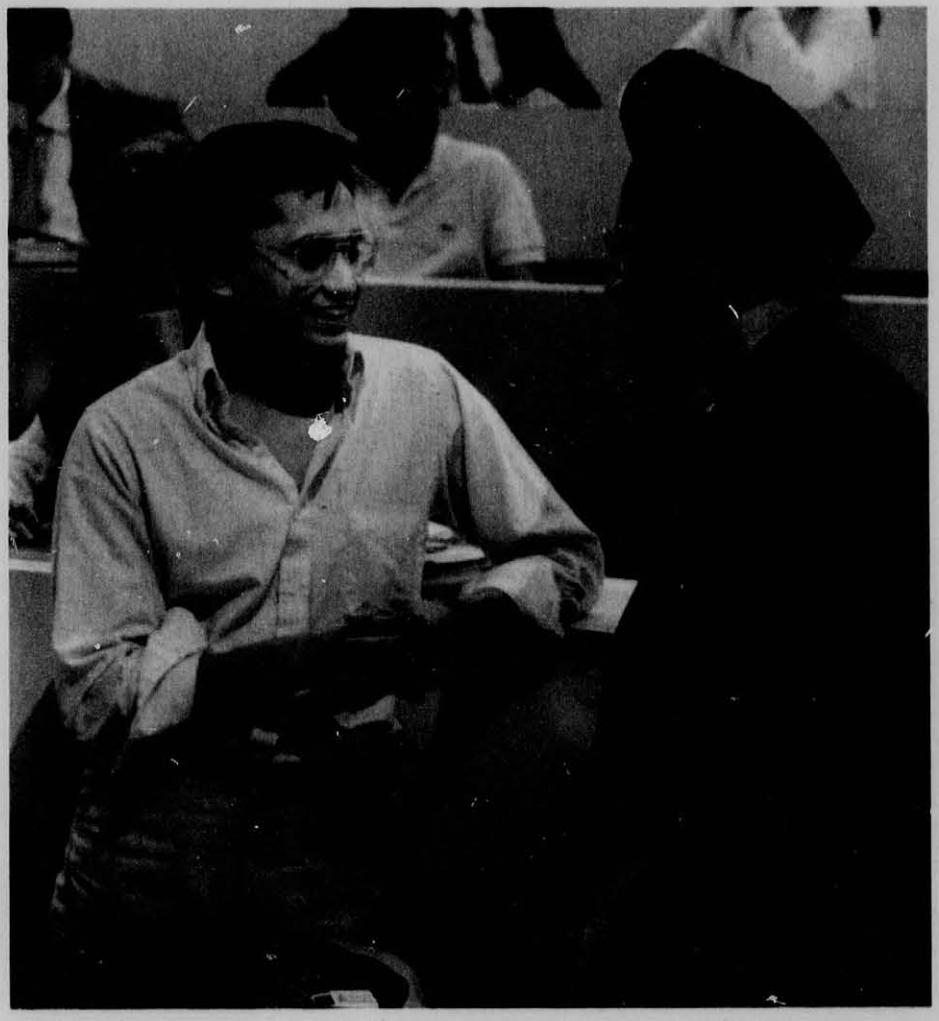
Motor Vehicles

All motor vehicles operated by students must be registered each year with the MIT Campus Police. Failure to register will result in a $25 fine. This registration is required whether or not a parking sticker is obtained. Students should also note that state law requires that out-of-state cars operated by students be registered with the Campus Police.

Parking facilities at MIT are limited. In general, the Institute cannot provide parking for resident students. With the approval of the Dean for Student Affairs, a limited number of spaces is available for assignment to students with physical handicaps requiring use of an automobile and to a few other undergraduates. Parking is prohibited and towing in effect on Memorial Drive in front of MIT between the hours of 7 and 10 am. Students are advised to avoid bringing an automobile to MIT, if possible.

Students who plan to bring motor vehicles to Cambridge should take careful note of the information regarding pertinent Massachusetts laws mailed with registration material. In addition, since the rate of car thefts in this state is one of the highest in the nation, serious consideration should be given to equipping automobiles with anti-theft devices.









Interdepartmental Study and Research

Advances in knowledge and concern with the functioning of modern society have led researchers to become interested in complex problems that can no longer be adequately resolved from the vantage point of a single academic department. There is thus an increasing tendency at MIT for faculty and students from different fields to work together in a variety of groups, laboratories, centers, and programs that cut across departmental or School lines. Some of these opportunities lead to degrees or form the basis for a "minor" program; many can be explored through the various interdepartmental organizations and research facilities available at MIT.

These interdepartmental educational opportunities and research facilities are listed in this chapter and described in detail. The specific opportunities for undergraduate and graduate students in each of these areas are outlined within the description of the program or facility.

Some of the interdepartmental programs and research facilities provide opportunities for undergraduates to engage in research or study as part of a departmental major, and some provide a way to broaden a student's educational experience. Undergraduates enrolled in a variety of departments may find valuable possibilities for thesis work and participation in the Undergraduate Research Opportunities Program (UROP).

Most of the Institute's major interdepartmental organizations and research facilities listed in this chapter offer graduate students opportunities for interdepartmental research, including thesis topics (and often research assistantships). Some of the interdepartmental educational programs have been formally approved for graduate students by the Committee on Graduate School Policy. An interested student must be admitted by one of the regular academic departments in order to participate in an interdepartmental program (except in Operations Research). Each of these programs has a standing faculty committee that administers the program, but degrees in the field of study are granted by the student's department of registration. The descriptions of these programs indicate in the title the advanced degree(s) that are offered; e.g., (S.M.), (Ph.D.). Other study or research opportunities may be fields of study that lead to advanced degree programs or as interdepartmental programs administered on a more ad hoc basis.

The opportunities for interdepartmental study and research at MIT include:

Acoustics
Archaeology and Ancient Technology (see Center for Materials Research in Archaeology and Ethnology)
Artificial Intelligence Laboratory
Astronomy and Astrophysics
Bates Linear Accelerator (see Laboratory for Nuclear Science)
Biomedical Engineering
Biotechnology Process Engineering Center
Bitter National Magnet Laboratory
Center for Advanced Engineering Study
Center for Advanced Visual Studies
Center for Biological Information Processing
Center for Cancer Research
Center for Cognitive Science
Center for Computational Research in Economics and Management Science
Center for Environmental Health Sciences
Center for Information Systems Research
Center for International Studies
Center for Materials Research in Archaeology and Ethnology
Center for Materials Science and Engineering
Center for Real Estate Development
Center for Space Research
Center for Technology, Policy, and Industrial Development
Center for Transportation Studies
Clinical Research Center
Cognitive Science Programs (see Center for Cognitive Science)
Concourse Program for First-Year Students
Draper Laboratory
Economics and Urban Studies
Energy Laboratory
Energy Study and Research
ESG (Experimental Study Group)
Health Sciences and Technology
Humanistic Studies (see Programs for Double Competence in Humanities/Social Science and Science/Engineering)
Integrated Study Program
Interdisciplinary Programs in Humanities
Interdisciplinary Research Opportunities for Undergraduates (see UROP)
International Food and Nutrition Program
Laboratory for Computer Science
Laboratory for Electromagnetic and Electronic Systems
Laboratory for Information and Decision Systems
Laboratory for Manufacturing and Productivity
Laboratory for Nuclear Science
Laboratory of Architecture and Planning
Law-Related Studies
Leaders in Manufacturing Program
Lincoln Laboratory
Management of Technology Program
Materials Processing Center
Media Laboratory
Middle East Program
Mineral Resources Engineering and Management
Mining and Mineral Resources Research Institute
MIT-Japan Science and Technology Program
Nuclear Reactor Laboratory
Oceanography and Oceanographic Engineering
Operations Research Center
Operations Research
Plasma Fusion Center
Power Engineering
Program in Polymer Science and Technology
Programs for Double Competence in Humanities/Social Science and Science/Engineering
Real Estate Development (see Center for Real Estate Development)
Research Laboratory of Electronics
Science, Technology, and Society
Sea Grant College Program
Spectroscopy Laboratory
Statistics Center
Technology and Development Program
Technology and Policy
Transportation (see Center for Transportation Studies)
Undergraduate Research Opportunities Program (UROP)
Undergraduate Seminars
Unspecified S.B. Degree Programs for Interdisciplinary Study
Wallace Astrophysical Observatory (see Astronomy and Astrophysics)
Wallace Geophysical Observatory
Whitehead Institute
Women's Studies

Acoustics

Acoustical study and research are carried out within the Departments of Mechanical Engineering, Ocean Engineering, Electrical Engineering and Computer Science, Aeronautics and Astronautics, and Architecture.

Acoustical work generally supports the principal activities within the departments, such as in communications, machine design, propulsion and guidance, and structural design. Subjects in acoustics have few prerequisites and can be readily taken by students from any department. **Undergraduates** should be able to take several acoustics courses from the offerings of various departments. At the **graduate** level, it is possible to set up more specialized interdepartmental programs of study and research in acoustics. The unspecified master's degree in engineering allows one to specialize in acoustics. Another possibility is to enter the doctoral program of one of the departments and to establish a special faculty committee with representatives of the appropriate departments for the program. The degree received may be departmental or designate a specialty in acoustics.

Acoustics subjects fall generally within three categories. The first consists of basic subjects at both undergraduate and graduate levels. These subjects are taught within the Departments of Electrical Engineering and Computer Science, Mechanical Engineering, and Architecture. A second group of subjects supports the various research activities in acoustics. These include subjects in speech communication, neural physiology and perception of speech, sound vibration and wave propagation, aerodynamic noise, and medical ultrasonics. A third set of subjects is in "professional practice," and includes noise control, architectural acoustics, and sonar applications. A complete listing of the various acoustics subjects is contained in the brochure *Acoustics at MIT*.

Students wishing further information should contact Professor Richard H. Lyon, Department of Mechanical Engineering, Room 3-366, MIT, Cambridge, Massachusetts 02139, (617) 253-2214.

Artificial Intelligence Laboratory

The primary goal of the Artificial Intelligence Laboratory is to understand how computers can be made to exhibit intelligence. Two corollary goals are to make computers more useful and to understand certain aspects of human intelligence. Current research includes work on robotics, English-language understanding, learning and automatic debugging, common-sense reasoning, engineering problem solving, manufacturing productivity, computer architecture, and human development.

Graduate students typically are enrolled in the Departments of Electrical Engineering and Computer Science, Mechanical Engineering, Brain and Cognitive Sciences, Mathematics, or Linguistics and Philosophy. **Undergraduates** get involved through UROP projects.

Robotics. This area includes studies in vision, tactile sensing, manipulation, and the intelligent connection of perception with action. Central problems are the formulation of representations and the exploitation of natural constraints.

Design and Analysis Systems. Engineers design, analyze, debug, and explain complex engineered systems using reasoning that is relatively deep. Understanding this reasoning requires the ability to deal with such notions as causality and the interaction of constraints. Applications apply particularly to mixed numerical and symbolic computing environments for scientists and engineers, testing and diagnosing electronic devices, and programming environments.

Learning and Natural Language. Recent work has concentrated on theories explaining how new situations can be analyzed in terms of remembered case studies and on ideas that enable the rules of natural language syntax to be inferred from examples. Applications are oriented toward supply decision makers with usable computer expertise.

Computing Concepts. Sophisticated ideas for programming languages and computer architectures are a major research theme. Current work focuses on massively parallel machines and on scalable, message-oriented models of computation.

Further information is available from Professor Patrick H. Winston, Director, Artificial Intelligence Laboratory, Room NE43-816, MIT Cambridge, Massachusetts 02139, (617) 253-6754.

Astronomy and Astrophysics

Observatories and Facilities

Teaching and research in astronomy and astrophysics at MIT are truly interdepartmental, involving more than 25 faculty members of the Departments of Physics; Earth, Atmospheric, and Planetary Sciences; Mathematics; Electrical Engineering and Computer Science; and Chemistry. The subjects offered and the opportunities for **graduate** and **undergraduate** research cover a correspondingly broad spectrum.

The observational programs emphasize the application of modern technology to the study of objects as diverse as the rings of planets and clusters of galaxies. For example, radio telescopes, as single dishes or transcontinental interferometer arrays, are used to determine the structure of radio galaxies and to analyze the formation of complex molecules in interstellar space. X-ray satellites are used to measure the temperature and composition of intergalactic matter and to study the properties of thermonuclear explosions on neutron stars. Plasma detectors on deep-space probes are used to explore the properties of the interplanetary medium and the magnetospheres of the planets out to Neptune. Radar scanners are used from Earth and from planet-orbiting spacecraft to map the topography of Venus. Two-dimensional CCD arrays are used for image analysis on optical telescopes. Looking toward the future possibility of gravity-wave astronomy, instruments for the detection of gravitational radiation are now under development.

Some of the theoretical research is related directly to observational programs as in the study of planetary ring systems, the interpretation of interplanetary plasma measurements, and the evolution of X-ray binaries. Other efforts are devoted to understanding the general circulation of planetary atmospheres, the dynamics of both isolated and interacting galaxies, and problems of relativistic and high-energy astrophysics ranging from the origin of the universe in the Big Bang to the formation of galaxies, the mechanisms of supernovae, and the origins of cosmic rays.

The George R. Wallace, Jr., Astrophysical Observatory is versatile facility for research and teaching in optical astronomy, and directly supports the growing student and faculty interest in astronomy and related science at MIT. The Observatory, located in nearby Westford, Massachusetts, has two optical telescopes of 16- and 24-inch diameter with unique electronic instrumentation. The telescopes are used in formal instruction for student research projects, and as testbeds for instrumentation to be used with larger instruments. Further information on

the Wallace Observatory may be obtained by contacting Professor James L. Elliot, Department of Earth, Atmospheric, and Planetary Sciences, Room 54-422, MIT, Cambridge, Massachusetts 02139, (617) 253-7556 or 253-6308.

The **Haystack Radio Observatory** provides opportunities for undergraduate and graduate student research, both for spectroscopy of the interstellar medium and for very-long-baseline interferometry. The Haystack Observatory is also located in Westford.

The **McGraw-Hill Observatory** at Kitt Peak in Arizona is operated jointly by MIT, the University of Michigan, and Dartmouth College. It has two telescopes of 52-inch and 95-inch diameter, both with modern instrumentation.

Experimental programs with student participation involve instruments launched on board satellites and interplanetary spacecraft. In addition, MIT students and staff observe at other installations such as the National Radio Astronomy Observatory in West Virginia and the National Astronomy and Ionospheric Observatory in Arecibo, Puerto Rico, and they use the telescopes of both the Kitt Peak National Observatory and the Cerro-Tololo Inter-American Observatory in Chile.

Astronomy and astrophysics subjects, which are offered at the **undergraduate** and **graduate** levels, are primarily given by the Departments of Physics, and Earth, Atmospheric, and Planetary Sciences. Further information, including a complete list of astronomy and astrophysics subjects, may be obtained by contacting Professor George Clark, Room 37-611, MIT, Cambridge, Massachusetts 02139, (617) 253-5842.

Biomedical Engineering

There are many **graduate** degree opportunities (Sc.D., Ph.D.) in biomedical engineering at MIT, and students and faculty in many departments are conducting research in this area. These research interests, spanning the life sciences, physics, and engineering, have led to the development of programs of graduate study for students wishing to pursue careers in these rapidly evolving fields. Each of these programs has evolved out of the interests and professional specialties of the participating faculty. Many are based primarily in the academic departments of the School of Engineering and therefore are available to students as regular departmental activities. Virtually all of the engineering studies are in collaboration with life scientists, many of whom are members of medical faculties and affiliated with teaching hospitals in the Boston area.

There are currently four graduate programs in biomedical engineering available to graduate students at MIT. These are (in order of increasing medical and clinical content): 1) departmental programs in the School of Engineering; 2) MIT Interdepartmental Doctoral Program in Biomedical Engineering; 3) Harvard-MIT Division of Health Sciences and Technology Doctoral Program in Medical Engineering and Medical Physics; and 4) combined M.D.-Ph.D. programs.

The choice among the first three of these programs depends on the desired breadth of exposure to the medical and life sciences and the career goals of the student, particularly with respect to the clinical aspects of biomedical engineering.

1) A student who is primarily attracted by a basic engineering discipline that is applicable to biological problems, and who intends to pursue a professional engineering career that may lie outside of the field of biomedical engineering, is advised to apply for the departmental program. A background in mathematics and the physical sciences is a necessary prerequisite for graduate study in biomedical engineering programs within the School of Engineering. Preparation in the biological sciences, though desirable, is not required. Active biomedical research is pursued in the Departments of Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics.

Further information on departmental programs may be obtained from the graduate registration officer of the appropriate department.

2) The Interdepartmental Doctoral Program in Biomedical Engineering at MIT has been designed for students who wish a broader exposure to the life sciences, and who wish to pursue research of an interdisciplinary character. This program is administered under the auspices of the Harvard-MIT Committee on Biomedical Engineering and Physical Sciences. The program is aimed at developing biomedical engineers who can function well in both the fields of engineering and life sciences as, for example, bioengineers concerned with control systems and with instrumentation for aerospace medicine; biomaterials scientists interested in developing materials for artificial organs and prosthetic devices; experts in fluid flow who are seeking a deeper understanding of how the cardiovascular system functions; and systems engineers interested in designing automated laboratories, model emergency rooms, operating rooms, and patient facilities. Graduate students from any department who possess or are completing an engineering master's degree may apply for admission. Students should normally apply for admission to the MIT engineering department most closely related to the field of their undergraduate major, and should contact Professor A. J. Grodzinsky, Room 38-377, MIT, Cambridge, Massachusetts 02139, (617) 253-4969. *The Guide to Biomedical Engineering and Physics at MIT and Harvard* describes both educational programs and research activities. Copies are available from Professor Grodzinsky at the above address.

3) The HST Doctoral Program in Medical Engineering and Medical Physics is a nominal five-year program designed to educate individuals who will be well qualified as engineers or physicists, and who, with extensive knowledge of the medical sciences, may engage in productive, independent investigation of important problems at the interface of technology and clinical medicine. The Program provides a thorough graduate experience in a classical discipline of engineering or physics, and also requires considerable study in the basic medical sciences. In addition, students are afforded a unique opportunity to learn important clinical skills and acquire an in-depth understanding of clinical care, medical decision making, and the role of technology in patient care.

To be considered for admission, students must have completed at least a B.S. degree in an engineering discipline or in physics. Those individuals who have completed only the bachelor's degree prior to matriculation in the Program must apply simultaneously to the HST Division and the appropriate graduate department. Admission to the MEMP Program requires affirmative assessment by both departmental and HST Admission committees. Students who have completed a master's degree need apply only to the HST Division. Further information may be obtained from Professor R. G. Mark, Room E25-519, MIT, Cambridge, Massachusetts 02139, (617) 253-7818.

4) The biomedical sciences curriculum of the Harvard-MIT Division of Health Sciences and Technology leads to the M.D. at Harvard Medical School and may be combined with studies leading to the S.M. or the Ph.D. in one of the MIT departments. Students interested in such combined degree programs must apply independently to the department of interest and to Harvard Medical School. Further information may be obtained from Professor R. G. Mark, Room E25-519, MIT Cambridge, Massachusetts 02139, (617) 253-7818.

Biomedical engineering is also of increasing interest to **undergraduate** students at MIT. Investigations on such varied topics as biomaterials, biological control systems, and mechanisms of sensory perception, to name only a few, involve faculty and students from most of the engineering departments. Much of this research is carried out in interdepartmental laboratories in collaboration with

workers from medical centers in the Boston area. Undergraduates wishing to explore this developing area have ample opportunity within their regular departmental major through elective subjects, special laboratory projects, and the senior thesis. These studies should be of special interest to students who are enrolled in a premedical curriculum. Further information may be obtained from Professor L. R. Young, Room 37-207, MIT, Cambridge, Massachusetts 02139, (617) 253-7805.

Biotechnology Process Engineering Center

Established at MIT through the National Science Foundation, the Biotechnology Process Engineering Center (BPEC) provides a unique opportunity for education and research at the forefront of biotechnology. At the BPEC, the fundamentals of advanced manufacturing technologies are developed through the applications of engineering principles to the life sciences. Another important objective of the BPEC is to establish active collaborative programs with industry that will train professionals in the disciplines of biotechnology, expand research activities, and promote innovation. The BPEC involves both undergraduate and graduate students and postdoctoral fellows. Research is led by 15 faculty members from the Departments of Chemical Engineering, Biology, and Electrical Engineering and Computer Science.

The BPEC centralizes the various programs available for the study of biotechnology and provides a structure for new educational initiatives. For undergraduates, a strong base in chemical engineering provides an ideal background for further studies in biotechnology. A liberal policy for elective courses in several departments is available to undergraduates in order to fulfill interdisciplinary needs and foster cross-disciplinary education. In addition, research opportunities in biotechnology are available to all MIT undergraduates through the MIT Undergraduate Research Opportunities Program (UROP). UROP positions, for pay or for academic credit, are available during the summer and the academic year.

Within the M.S. and Ph.D. programs in Chemical Engineering, biotechnology educations focuses on the necessary core subjects in Chemical Engineering, complemented by electives in Chemical Engineering, Biology, the Program in Applied Biological Sciences, and Chemistry. Alternatively, the M.S. and Ph.D. program in Biochemical Engineering is available through the Program in Applied Biological Sciences. In this program, other elective subjects are drawn from the departments of Chemical Engineering, Chemistry, and Biology, and the doctoral qualifying examinations are prepared by members of the three departments.

There are four main focal points for research at BPEC:

Genetics and Molecular Biology: Work is directed toward the synthesis of human proteins (by gene insertion into animal cells and yeasts). Specific problems include control of RNA processing and translation, active expression in stationary cells, and genetic approaches to control protein excretion.

Bioreactor Design and Operation: This segment of the research program involves the development of fundamental engineering principles for large-scale production using animal cell culture, including bioreactor design, scale-up, and operation.

Efficient Recovery of Biochemical Processes: Biologists and engineers work together to develop innovative yet generic solutions for the recovery of a variety of protein products and to elucidate the fundamentals of unit operation of biochemical product recover. Current programs include work on cross-flow membrane filtration, extraction of intracellular proteins, affinity separations chromatography, and continuous adsorption processes.

Biochemical Process Systems Engineering: Work is devoted to the development of systematic engineering approaches and tools for the analysis, evaluation, and control of complete biochemical process flowsheets. Projects include design of expert systems for the development of biochemical processes; synthesis and simulation in the design of complete bioprocessing systems; and systematic approaches to modeling, analysis, and control of biological processes.

Further information may be obtained from the Office of the Director, Professor Daniel I. C. Wang, Biotechnology Process Engineering Center, Room 20A-207, MIT, Cambridge, Massachusetts 01239 (617) 253-0805.

Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory, supported by the National Science Foundation, conducts a program of research and development in science and engineering in areas involving magnetic fields.

Continuous fields up to 30 tesla are available in a variety of configurations. High magnetic field and high resolution nuclear magnetic resonance spectrometers are used for studies of molecules of biological interest. Both the high field magnets and the nuclear magnetic resonance spectrometers are made available on a routine basis to research groups from other MIT departments and from institutions throughout the world. In addition, the Laboratory operates pulsed magnets (giving fields up to 45 tesla) and a magnetically shielded room of walk-in size.

The Laboratory's solid-state physics research program is an experimental and theoretical study of semiconductors, magnetic materials, and superconductors. Molecular biology studies are carried out using high-resolution nuclear magnetic resonance spectrometry and the Mossbauer effect.

The Laboratory also conducts research and development programs aimed at the practical application of magnetic fields to technology and medicine. Current projects include studies of the weak magnetic fields of the human body, studies of magnetic separation techniques, and development of nuclear magnetic resonance imaging systems.

Collaborative programs are carried out with the Departments of Physics, Electrical Engineering and Computer Science, Mechanical Engineering, Nuclear Engineering, Materials Science and Engineering, Chemistry, and with the Plasma Fusion Center. These collaborative programs include participation by undergraduate and graduate students working on theses. Undergraduate students in the UROP program and others are also employed.

Additional information may be obtained from the Director, Professor David Litster, Building NW14-3220, MIT, Cambridge, Massachusetts 02139, (617) 253-6801.

Center for Advanced Engineering Study

The primary goal of the Center for Advanced Engineering Study (CAES) is to improve and extend the capabilities and effectiveness of professionals in engineering and the sciences by providing critical learning opportunities on campus and at the workplace. Through its varied programs, the Center creates vital communication links between industry professionals and the academic/research community at MIT. In this way, the Center plays a critical role in transferring important developments in new and emerging scientific and technological fields to industry.

The Advanced Study Program at CAES is intended for engineers, scientists, and technical managers who wish to pursue academic studies at MIT that are tailored to their needs and backgrounds. Participants attend academic courses and seminars, perform individual studies guided by faculty members, and participate in ongoing research projects. Enrollment may be for one or more semesters, either on a full-time or part-time basis. Participants are provided with offices, computer facilities and a videotape library. A certificate is awarded upon satisfactory completion of the Program.

CAES Video Courses extend the on-campus academic program through the distribution of video-based education. CAES has produced more than 50 in-depth, high-quality video courses in engineering, science, and management. Each course is taught by a leading authority in the field and is designed specifically for use by professionals at the workplace. A course manual with problems and solutions is included to enhance the learning experience. An estimated 30,000 learners at a distance utilize these courses annually. Recent releases include Signals and Systems: An Introduction to Analog and Digital Signal Processing, by Professor Oppenheim; Structure and Interpretation of Computer Programs, by Professors Abelson and Sussman; Advanced Composites, by Professors Mar and Lagace; Data Networks, by Professors Bertsekas, Gallager, and Humblet; and Materials Processing: Mathematical Modeling of Processes, by Professor Szekely and Dr. Wahnsiedler.

The Center operates a professional-level studio complex in its Building 9 headquarters, where video courses are developed with the faculty. Broadcast-quality, multicamera recording and editing equipment is used in the production of studio as well as in-classroom courses and symposia. CAES staff manages and operates all aspects of video production. Studio courses in development include Image Processing, by Professor Schreiber and Dr. Netravali; Analysis of Welded Structures, by Professor Masubuchi; and Machinery Noise and Diagnostics, by Professor Lyon.

In addition, CAES, in cooperation with the Industrial Liaison Program, videotapes on-campus symposia that focus on particular areas of ongoing research of specific interest to industry. The videotapes are made available to industrial organizations in the interest of wider dissemination of MIT technology. Recent videotaped symposia include Manufacturing in the 1990s; Expert Systems from the User's Perspective; The Science and Technology of Manufacturing; Biotechnology Process Engineering; Metal and Ceramic Matrix Composites: Processing, Microstructure, and Properties; Frontiers in Metallurgical Research; Computer Models and Modeling for Negotiation Management; Speech Communication and Processing; and High-Temperature Superconductivity: Implications for Industry.

The Center works closely with the faculty in the development of educational programs. The selection of topics and the breadth of the coverage are influenced by industry needs. The coupling between CAES and the MIT campus is also strong. Most video courses produced by the Center are available at the MIT libraries for use by students, faculty, and staff, and the symposia are always open to the MIT community. In addition, the Center, in partnership with MIT's Information Services, is installing a satellite downlink to receive a variety of educational programs, which will be made available to the MIT community via the campus television network.

The Center participates in a unique initiative to provide continuing education for electrical engineering faculty in US colleges. Several two-week long intensive courses are offered during the summer by various participating universities and industrial organizations at various locations in the US. Topics vary from Artificial Intelligence to Digital Signal Processing. These programs are offered under the aegis of the American Society for Engineering Education.

Finally, in cooperation with industry, CAES conducts research in program development as well as innovative educational methodologies and delivery systems.

For more information on CAES and its various programs, contact Professor Shaoul Ezekiel, Director, Center for Advanced Engineering Study, Room 9-215, MIT, Cambridge, Massachusetts 02139 (617) 253-3783.

Center for Advanced Visual Studies

The Center for Advanced Visual Studies provides artists of achievement with the opportunity to explore new artistic forms. Collaboration through a working dialogue among artists, scientists, and engineers is of primary importance in the exploration of new creative objectives. Mutually beneficial contact between artist and scientist allows the artist to develop the technical competence to utilize advanced technology.

The Center's main areas of interest are: environmental art and design; developmental artistic media work; interaction of art, science, and technology; celebrations; and education toward the new arts — video, holography, computer-aided design and programming, laser art, and sky art.

A limited amount of work space also is available for a small number of research fellows and graduate students. Undergraduates may participate in the Center through UROP. A catalogue listing the Center's educational offerings, in association with the Department of Architecture, is available in the Office of the Director, Professor Otto Piene, Building W11, 40 Massachusetts Avenue, MIT, Cambridge, Massachusetts 02139, (617) 253-4415.

Center for Biological Information Processing

The Center for Biological Information Processing, established in 1984 within the Whitaker College of Health Sciences, Technology, and Management, serves as a focal point for collaboration among researchers in artificial intelligence, engineering, and the neurosciences. The purpose of the Center is to foster an interdisciplinary approach to the study of information processing in the brain, where computational theories in the areas of vision and motor control are developed and tested within the framework of neurophysiological, psychological, and other experimental approaches.

The Center brings together faculty, postdoctoral fellows, visiting scientists, and students. Through seminars, collaborative research efforts, and informal interaction, the Center promotes communication among researchers from diverse disciplines, complementing the computational approach with the necessary experimental talent. These activities enable researchers with computational backgrounds to study the brain sciences, while neurobiologists and experimental psychologists train in the computational research of brain function.

Research opportunities at the Center are available for a small number of graduate students who meet the requirements for admission in the Departments of Biology, Brain and Cognitive Sciences, Electrical Engineering and Computer Science, Mathematics, Physics, and the Harvard-MIT Division of Health Sciences and Technology. The Center offers a limited number of UROP opportunities for undergraduate students.

Further information regarding current research projects, and a listing of memos published by members of the Center are available from the Assistant to the Director, Room E25-201, MIT, Cambridge, Massachusetts 02139, (617) 253-0551.

Center for Cancer Research

The Center for Cancer Research provides facilities for interdepartmental work in various phases of fundamental cancer research. The Center's faculty are drawn from the Department of Biology. Graduate students in any of the MIT departments may ask to do doctoral thesis research under the supervision of the faculty of the Center. If accepted, they may be eligible for support as research assistants in the Center. Opportunities for undergraduate research are available through the UROP program. Seminars in cancer research both for credit and as public colloquia of the Center are available. Further information may be obtained by contacting the Office of the Director, Professor Phillip A. Sharp, Room E17-110, MIT, Cambridge, Massachusetts 02139, (617) 253-6400.

Center for Cognitive Science

Cognitive Science Programs

The Center for Cognitive Science provides an intellectual and administrative focus for individual and collaborative research in cognitive science at MIT. In addition, a committee of the Center disseminates information about graduate and undergraduate study in cognitive science.

Members of the Center represent the Departments of Electrical Engineering and Computer Science, Linguistics and Philosophy, and Brain and Cognitive Sciences (which offer subjects appropriate for training in cognitive science), as well as the Artificial Intelligence Laboratory and the Research Laboratory of Electronics.

A number of cooperative activities involving members of the Center and scientists at other institutions with programs in cognitive science are planned or in progress, and the members of the Center maintain active relations with scientists working at other academic, medical, and research institutions in the Boston area.

The Center administers a program of postdoctoral fellowships that bring young scholars to MIT to work with members on the Center's research projects. In addition, a visiting scientist program is maintained that brings more senior researchers to the Center. The Center also coordinates a number of research projects in the areas of cognitive science pursued by visiting and permanent members of the Center. Computer-based laboratory and research facilities are maintained within the Center to support the conduct of such research.

A Cognitive Science Seminar, a series of colloquia, and the publication of an Occasional Paper Series serve to disseminate scientific information and provide for the mutual exchange of students and workers in the field.

Further information may be obtained from Professors Samuel Jay Keyser and Steven Pinker, Codirectors, Room 20D-212, MIT, Cambridge, Massachusetts 02139, (617) 253-4149 or 253-4141.

The undergraduate bachelor's degree program in cognitive science is described under the Department of Brain and Cognitive Sciences in Chapter VII of this catalogue.

At the graduate level, no formal interdisciplinary degree program is offered at present. Graduate students who wish to have information or guidance about available resources across departments should consult the chairman of the Committee on Graduate Studies in Cognitive Sciences, Professor S. J. Keyser, Room 20D-212, MIT, Cambridge, Massachusetts 02139,(617) 253-4141.

Center for Computational Research in Economics and Management Science

This Center's purpose is to advance knowledge about modeling in economics, statistics, and management. This is accomplished through algorithmic research and related software development, performed by researchers representing the varied quantitative disciplines that underlie modern computer-intensive modeling. These disciplines include econometrics, statistics, computer science, and operations research. Computer implementation is performed using interactive tools, of which the single most important is a comprehensive software environment called TROLL. TROLL contains programming tools and standard functions that facilitate the rapid implementation of experimental algorithms and also provides a modeling environment for applied studies. The system provides all standard techniques, and many experimental ones, for building and using econometric models.

Recent research at the Center has focused on the evaluation and improvement of model reliability using graphics, methods for coping with multicollinearity, nonlinear optimization, robust estimation, ARIMA time-series models, and the use of artificial intelligence concepts in statistical or econometric model building.

The Center's research complements activities in several MIT departments and laboratories. The links include active participation in Center projects by faculty members of the Sloan School of Management; collaboration with the Statistics Center and the Operations Research Center on projects of mutual interest; and use of Center-developed software by the Departments of Economics, Political Science, and Civil Engineering.

Several graduate students work as research assistants at the Center, and undergraduates, participate in UROP projects. Students sometimes use the Center's resources in doing theses.

Further information may be obtained from the Director, Professor Roy E. Welsch, Room E40-129, MIT, Cambridge, Massachusetts 02139, (617) 253-8411.

Center for Environmental Health Sciences

The Center for Environmental Health Sciences was established through the collaborative efforts of faculty in the Departments of Chemistry, Chemical Engineering, the MIT Energy Laboratory, and the Program in Toxicology in the Whitaker College. These faculty are now joined by faculty from the Departments of Biology, Civil Engineering, and Materials Science and Engineering to form an institute-wide association with the common goal of identifying the chemicals responsible for induction of cancer, genetic defects in humans, and recognizing the environmental sources of those chemicals and devising appropriate means to reduce human exposure. The Center is funded by the National Institute of Environmental Health Sciences. Its associated research programs are funded by NIEHS, the Office of Health and Environmental Research (US Department of Energy), the National Cancer Institute and the American Cancer Society. These research programs have provided challenging interdisciplinary problems for graduate and undergraduate students.

Oil and coal combustion effluents, food contaminants, hazardous waste storage and disposal, and air and water pollution are among the practical problem areas in which multidisciplinary teams are at work. A primary mode of research involves analytical chemists working with engineering researchers to measure and identify the chemical components from experimental and practical combustion systems or waste sites. Toxicologists evaluate the biological activity of the raw mixtures by measuring their mutagenic potency in bacteria and human cells. The combination of analytical chemistry and toxicology is then used to identify specific compounds in the mixtures that are responsible for the biological activity.

Future research and educational efforts will be based on the Center's development of means to measure the presence and biological effects of environmental chemicals directly in humans. The goal is to discover which environmental chemicals (if any) are primarily responsible for significant genetic changes in ordinary humans. A special emphasis is given in those genetic changes known to be required for human cancer. Finally, the Center is home for the Program in Genetics and Toxicology, which fosters collaborative studies among toxicologists and molecular biologists at MIT and Harvard with interests in basic mechanisms of genetic change.

The Center Director is William G. Thilly, Professor of Applied Biology, Room E18-666, MIT, Cambridge, Massachusetts 02139, (617) 253-6220.

Center for Information Systems Research

The Center for Information Systems Research (CISR) was established at the Sloan School of Management in 1974. CISR's activities focus on research aimed at improving the effectiveness of information-processing tools and techniques available to managers in the private sector and policy makers in the public sector. There is a recognized need to institute more effective relationships between academics and private and public sector managers in a joint effort to improve the management of information technologies.

Research at CISR is pragmatic, problem-based, and application-driven. Research efforts are performed primarily in application areas of interest to managers and policy makers. A set of corporate sponsors provides both funding and assistance in defining and investigating significant research areas. Research on fundamental issues affecting both the public and private sectors is being performed in such areas as 1)managerial use of computers, 2) Information Technology, 3) the management of the information systems function, and 4) the impact of information systems on organizations. CISR disseminates significant research findings to the information systems user community through teaching, seminars, working papers, and publications.

The background of CISR's faculty ranges from computer science and electrical engineering to law, psychology, and organizational behavior.

Each year, a number of master's degree **graduate** students in management information systems perform their thesis work and course projects in conjunction with ongoing CISR research. In addition, Ph.D. and master's students are often involved in CISR projects as research assistants.

Further information about the Center may be obtained by contacting the Office of the Director, Dr. John F. Rockart, Room E40-193, Sloan School of Management, MIT, Cambridge, Massachusetts 02139, (617) 253-2348.

Center for International Studies

The Center for International Studies engages in research on international issues and on foreign developments that are of international interest. The Center is dedicated to advancing knowledge of comparative and international studies as well as with policy analysis. There are opportunities for **graduate** students and visiting scholars to participate in the Center's research projects. The Center also has an active program of research workshops and visitors' seminars.

Located within the Center is the Defense and Arms Control Studies Program — a graduate teaching and research program. The teaching program is closely associated with the Department of Political Science and incorporates an important focus on science and technology. The research program and a summer program on nuclear weapons and arms control are under the auspices of the center.

The Soviet Security Studies Working Group addresses topics in Soviet military policy such as Soviet use of mathematical modeling in military planning; weapons innovation, research and development; and the structure and influence of the Soviet defense industry.

The Center also maintains the MIT-Japan Science and Technology Program that provides internships in Japan for MIT science and engineering students with Japanese language capabilities, supports a variety of Japan-related research at MIT, maintains an interdisciplinary project on the Japanese technology process, and sponsors workshops and symposia.

The International Food and Nutrition Program (IFNP) is also located within the Center. The IFNP has an active research program, and brings together scholars and practitioners in the field of international nutrition.

Among the seminars and workshops sponsored by the Center are the MIT-Harvard Joint Seminar on Political Development, the MIT-Boston University South Asia seminar, the Emile Bustani Middle East seminar, the Political Economy of Advanced Industrial Nations seminar, the Institutional Perspectives on the State in Third World Development workshop, the Defense and Arms Control Studies seminars, and the Future of International Migration seminars.

The Center also maintains research activities in the fields of international science, technology and public policy, energy policy, international conflict, communications policy, and international environmental issues.

Further information may be obtained from the Director, Professor Myron Weiner, Room E38-648, MIT, Cambridge, Massachusetts 02139, (617) 253-3140.

Center for Materials Research in Archaeology and Ethnology

Archaeology and Ancient Technology Program

The **Center for Materials Research in Archaeology and Ethnology** (CMRAE) encourages new directions for research in anthropology, archaeology, art history and related humanistic and social science disciplines by providing them with an expanded technical base in the sciences of organic and inorganic materials. The Center was established in 1977 and includes eight institutions in the greater Boston area: Boston University, Brandeis University, Harvard University, the University of Massachusetts, MIT, the Museum of Fine Arts of Boston, Tufts University, and Wellesley College. MIT serves as the Center's coordinating institution.

The Center's research activities are carried out in a network of shared laboratories at member institutions, which are used by students and faculty of those institutions as well as by visiting scholars and graduate students who join the Center for shorter periods. The materials research laboratories include, among others metallurgy, ceramics, lithics, archaeobotany, and zooarchaeology. The research program of the Center emphasizes rigorous laboratory study of artifacts and other kinds of cultural remains in order to determine the nature and structure of the materials of which they are composed and the extraction and processing regimes they have undergone.

The Center offers graduate-level subjects in the CMRAE Graduate Laboratory (20B-012). These are open to **graduate** students and **senior undergraduates** from all participating institutions. Each subject is heavily laboratory oriented, runs for a full year, and covers a single class of materials (e.g., ceramics or metals), or a method for interpreting archaeological data (e.g., computers in archaeology).

The Center runs a Summer Institute, which offers a one-month, intensive laboratory course open to graduate students and scholars from institutions throughout the United States and abroad.

Further information about the Center may be obtained from the Director, Professor Heather Lechtman, Anthropology/Archaeology Program and Department of Materials Science and Engineering, Room 8-138, MIT, Cambridge, Massachusetts 02139, (617) 253-1375.

MIT also offers an **undergraduate** program in **Archaeology and Ancient Technology**. Through a combination of archaeological fieldwork, laboratory studies, and subjects, this program attempts to improve the understanding of how pre-modern people adapted their material environment to their needs. We also study how cultures, interacting with materials, produced technological systems which, in turn, helped to shape the cultures themselves. This area of study combines the scientific examination and experiments of the materials laboratory, the scientific excavation of archaeological sites, the aesthetic feel of the technology and appreciation of its products, and the historical and anthropological study of the contexts of the technologies in specific places and times. The subjects, given in the Anthropology/Archaeology Program and in the Department of Materials Science and Engineering, focus on different ancient societies and different ancient technologies, and on the ethnographic record of the use of materials and techniques in the production of art and material culture in general.

The specific projects currently under study in the Laboratory for Research on Archaeological Materials and in the field include examination of pre-Columbian metalworking in the Andes and in Mesoamerica, an investigation of the change from tempera to oil medium in painting of the Italian Renaissance, and a study of a pottery-making village in coastal Ecuador. Interested students should contact Professor Heather Lechtman, Room 16-401, MIT, Cambridge, Massachusetts 02139, (617) 253-2172; or Professor Arthur Steinberg, Room 20B-131C, 253-6956.

Center for Materials Science and Engineering

Major research programs currently supported by the Center emphasize interdisciplinary research in the following areas of thrust: 1) superconductivity, 2)phases and phase transitions, 3) synthesis and properties of novel polymers, 4) deformation and fracture of high-temperature alloys, and 5) innovations in steel technology. These programs are funded primarily through a grant from the National Science Foundation.

Participating in CMSE-funded programs are faculty groups from the Departments of Chemical Engineering, Chemistry, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear engineering, and Physics. **Graduate** and **undergraduate** students participate actively in all aspects of the CMSE research program. Actual appointments are handled by the academic departments.

CMSE maintains excellent modern central service facilities such as crystal growing and characterization laboratories; spectroscopic facilities; scanning, transmission, and scanning-transmission electron microscopy; analytical compositional analysis; ion microprobe; ion implanter; production of rapidly quenched particulates of metallic, ceramic, electronic, and polymeric materials; state-of-the-art high-resolution X-ray scattering at the Brookhaven National Light Source; X-ray diffraction and X-ray topographic techniques; a polymer facility; and scanning Auger, ESCA, and SIMS analysis available in the Surface Analytical Facility. Also available are the von Hippel Reading Room and a student machine shop.

Annual MIT reports of research entitled *Research in Materials at MIT* and *Polymer Research* are available through CMSE Administrative Office, Room 13-2098, MIT, Cambridge, Massachusetts 02139.

Center for Real Estate Development

Real Estate Development (S.M.)

The **Center for Real Estate Development** provides an intellectual focus for research on issues affecting the development process. Faculty associated with the Center are drawn from the Departments of Architecture, Urban Studies and Planning, Civil Engineering, Economics, and the Sloan School of Management. Current research interests of the Center include international capital flows and their impact on domestic real estate markets; the interaction between tax policy, monetary policy, and the availability of capital for development; understanding the dynamics of market response to disequilibrium in the supply and demand for rental housing; the process by which building and public spaces combine to form cities; the evolving structure of the real estate industry; affordable housing; and research on new forms of public/private prospects.

The Center encourages interaction between members of the development industry and the academic community through seminars, colloquia, lectures, and a series of summer courses. The Center is supported in part through memberships from firms and individuals active in the development industry.

The Center also serves as the home for the **Master of Science in Real Estate Development** program, an interdepartmental degree program which combines education in design, planning, construction, management, finance, and marketing. The program is intended to prepare students to assume positions of responsibility in private development companies, financial institutions, government agencies, nonprofit development organizations, and consulting firms. The program requires 12 months of intensive study. Further information about the Center or the Master of Science in Real Estate Development may be obtained from James McKellar, Director, Center for Real Estate Development, W31-310, MIT, Cambridge, Massachusetts 02139.

Center for Space Research

The Center for Space Research offers students, faculty, and professional research staff opportunities to participate in a broadly based program of space-related research. Its projects draw upon the interests and expertise of scientists and engineers from many MIT departments and laboratories. Research programs are carried on, for example, in X-ray and planetary astronomy, space plasma and gravitational physics, and the life sciences. These experimental studies usually involve experiments carried by balloons, sounding rockets, orbiting satellites, or deep space probes. The experimental programs are supplemented by closely related programs of ground-based research in similar fields and by laboratory development of suitable instrumentation for the space-based and ground-based experiments. An active program of theoretical studies in astrophysics is also supported by the Center.

Laboratory facilities include X-ray sources, particle accelerators, vacuum chambers, and conventional electronic test and machine tool equipment. Extensive data handling and computational facilities are available for the analysis and reduction of scientific data. An experienced and well-equipped group of engineers and technicians provides design, construction, and testing of experiments in support of the flight programs.

The variety of scientific and technical problems that arise in these investigations affords numerous opportunities for **graduate** thesis research. In addition, there is major participation by **undergraduate** students in programs of data analysis and in the development of new instruments. Further information may be obtained from the Office of the Director, Professor Gordon H. Pettengill, Room 37-241, MIT, Cambridge, Massachusetts 02139, (617) 253-7501.

Center for Technology, Policy, and Industrial Development

The Center for Technology, Policy, and Industrial Development brings together on-campus resources for teaching and research of science- and technology-intensive policy issues. Current initiatives involve faculty and students from engineering, science, law, planning, management, and the social sciences. Participants from the public policy and private sectors join with MIT personnel in investigating how technology and industrial development may be advanced in a socially responsible manner.

Established in 1985, the Center encompasses several major programs including the International Motor Vehicle Program, the Hazardous Substances Management Program, the Material Sciences Laboratory, and research into the semiconductor industry. These programs are international in scope. In addition, independent researchers are pursuing studies in environmental management and decision making, risk assessment, energy management, and the ethical implications of industrial development abetted by technology.

The centerpiece of the educational initiative at the Center is a Master of Science degree program in Technology and Policy. The Technology and Policy Program also offers a Ph.D. (see description under Technology and Policy in the chapter). The faculty of the Hazardous Substances Management Program has developed a series of four related courses for **graduate** and **undergraduate** students covering the technical, managerial, and decision making implications of industrial

chemicals in the environment. Seminars and meetings designed to maximize the sharing of information and perspectives between academics, policy makers, and industry personnel address current issues under consideration by the ongoing research programs.

Graduate and **undergraduate** students interested in further information on the Center may contact the Director, Professor Daniel Roos, Building E40, MIT, Cambridge, Massachusetts 02139.

Center for Transportation Studies

Transportation (S.M.)

The **Center for Transportation Studies** was established to promote interdepartmental cooperation in innovative research and to provide a focal point for educational programs in transportation within the Institute. The Center's research involves all modes of transportation, both passenger and freight, in both the public and private sectors. It ranges from broad conceptual planning to the specifics of equipment design and operations analysis.

The Center promotes interaction among faculty members from all Schools at MIT as well as other universities and organizations concerned with transportation, recognizing that the solution to complex problems requires close ties between technological possibilities and their social, economic, ecological, and political ramifications.

Recent research projects include development of algorithms and computer software for logistical and network problems; urban and suburban congestion; the development of railroad track maintenance models; load planning for LTL trucks; studies of the airline industry under deregulation; development of dynamic models of transportation systems; expert systems applied to transportation problems; finding ways of improving productivity in railroads, trucking, and transit; the design of transit networks; comparisons of express bus and rail rapid transit; large-scale database systems in transportation; development of specific standards for highway maintenance and study of the performance of materials used in road construction; concrete bridge deck deterioration; studies of railroad equipment and automation and how they might be improved; the economics of ocean transportation of oil; and guidelines for urban planning. The Center also has been involved in major projects in Egypt, Spain, and Brazil dealing with infrastructure, railroads, and operations management. Research sponsorship includes a range of governmental and industrial organizations affording students wide opportunities for involvement in newly evolving research areas. Full-time and part-time research assistantships are awarded to **graduate** students each year. **Undergraduates** also may participate in sponsored research through UROP.

Graduate programs leading to the master's and doctoral degrees, as well as professional training, are available through the departments associated with the Center, including Aeronautics and Astronautics, Civil Engineering, Economics, Mechanical Engineering, Ocean Engineering, Political Science, Sloan School of Management, and Urban Studies and Planning.

The **Master of Science in Transportation**, an interdisciplinary degree offered by graduate departments, but administered by the Center, is designed to prepare students either for careers in transportation or for doctoral work. Students with a variety of backgrounds including engineering, social sciences, management, architecture, urban studies, and operations research participate in the program. Entering students should have a basic knowledge of economics, calculus, and probability.

The degree requirements include 1) the satisfactory completion of at least 72 units (typically 7-9 subjects), including 18 units in core subjects, 36 units in a program area, and 18 units of electives, and 2) the presentation of an acceptable thesis. The specified core consists of two subjects — Transportation Systems Analysis and Transportation Economics — and establishes a common methodological framework for analyzing a broad spectrum of transportation problems.

The remainder of the program builds upon specific program areas of professional interest, such as air, ocean, urban, or freight transportation; transportation systems analysis; and transportation logistics and carrier management.

Students admitted to the Master of Science in Transportation may propose programs of work in a second field leading to a second master's degree. Some examples of second areas include engineering, operations research, urban studies, and management. The student must be formally admitted for study in the second field and must apply for admission at least two regular terms before completion of the program. Normally, the student must complete the subject requirements for both degrees but may submit a joint thesis.

The Center for Transportation Studies attempts to provide financial assistance, in the form of fellowships and research and teaching assistantships, to all qualified students in fields where the Center is active.

Students interested in coming to MIT for transportation studies or in learning more about the Center and its programs should write to Professor Joseph M. Sussman, Director, Center for Transportation Studies, Room 1-123, MIT, Cambridge, Massachusetts 02139. For each admitted student an appropriate department of registration will be selected based on the individual's background and area of specialization.

Clinical Research Center

The MIT Clinical Research Center is a small, fully equipped and staffed research hospital on campus that enables interested scientists to perform research with human subjects and allows students at all levels to gain experience with human subjects and human disease. Research projects in progress are in the areas of metabolism, psychiatry, neurology, and clinical pharmacology. Most projects involve collaboration between basic and clinical scientists.

The facilities of the Center are open to all departments in the Institute, and its principal investigators are faculty members from many different departments. Although most patients hospitalized in the Clinical Research Center come from the Boston area, many are referred from other parts of the United States or from abroad. Research opportunities are available for **undergraduate** and **graduate** students contemplating careers in the medical sciences and for postdoctoral physicians.

Further information may be obtained by contacting the Office of the Director, Dr. Richard J. Wurtman, Room E17-445, MIT, Cambridge, Massachusetts 02139, (617) 253-3091 or 253- 3092.

Concourse Program for First-Year Students

Freshmen who wish to have the ambiance of a small school in their first-year studies may elect the Concourse Program. Concourse offers the standard curriculum for freshman year taught by MIT faculty in the sciences and humanities. A group of about 60 students take these courses and are encouraged to work together. Faculty and tutors are available to students directly. The program covers, and provides credit for, the Institute Requirements of the first year.

Draper Laboratory

A number of research organizations in the Boston-Cambridge area have close ties with MIT faculty members that may lead to opportunities for interdepartmental research. In particular, the Charles Stark Draper Laboratory maintains a relationship with the Institute that permits students to engage in joint research activities.

The Charles Stark Draper Laboratory (formerly the Instrumentation Laboratory) separated from MIT on July 1, 1973, to become an independent nonprofit research and educational organization. Mechanisms exist to permit the continuation of joint research activities and to allow the Laboratory to continue its unique contributions to the Institute's educational program.

The professional field of interest has traditionally been the instrumentation of practical problems in dynamic geometry, e.g., guidance and control of aerospace and marine vehicles. The Laboratory is mission-oriented. Probably the most publicized achievement of the Laboratory has been the Apollo guidance and control system. Draper Laboratory leadership in the US space program is continuing with the Space Shuttle Program. In addition, the Laboratory has been broadening its areas of activities in instrumentation to other fields such as geophysical and oceanographic engineering.

The Laboratory experience in instrumentation has resulted in new computer science activities and software applications in industrial automation, control for advanced energy systems, and specialized communication.

A number of MIT faculty members maintains a close association with the Laboratory, and thesis research opportunities exist that fulfill the residency requirement for an MIT degree in all phases of systems engineering, including basic theory, mathematical analysis, computer studies, component design and evaluation (mechanical, electrical, and optical), and system synthesis. Students are in direct contact daily with the professional staff of engineers and scientists of the Laboratory, and thus learn to appreciate the economic and human, as well as the technical, aspects of a system. **Undergraduate** and **graduate** students also may be employed by the Laboratory and work directly on a project. These opportunities provide an excellent technical internship that greatly broadens the students' educational experience.

Draper Laboratory, within walking distance of the main campus, is located at 555 Tech Square, Cambridge, Massachusetts 02139. Further information may be obtained by contacting Dr. David Burke, (617) 258-2393, or Institute extension 182-82393.

Economics and Urban Studies

A doctoral program is offered jointly by the Departments of Economics and Urban Studies and Planning at MIT. This program aims to integrate the analytic emphasis of economics, together with its research opportunities, with the institutional and policy orientation of urban studies. Both research and active intervention into urban problems benefit from such a combination because of the complexity and context-boundedness of urban issues. A wider variety of career opportunities is available than to specialists in either field alone. Students desiring to enter the program must be admitted to both departments and then explicitly to the Joint Program. Specific requirements are as follows: *Economics* — the same as for the Economics Ph.D. except 1) only two major fields and no minor, instead of two major and two minor fields; 2) economic history is not required. *Urban Studies* — The same as for the USP Ph.D. except: substitution of an Economics general examination field for one of the required Urban Studies fields. One dissertation is required, with acceptance by both departments. The program is administered by an informal Standing Committee.

Further information is available from Professor Jerome Rothenbeg, Room E52-355, MIT, Cambridge, Massachusetts 02139, (617) 253-2674, or from Professor William C. Wheaton, Room E52-274A, 253-1723.

Energy Laboratory

Energy Study and Research

The **Energy Laboratory** was established in 1972 to provide a focus for strengthening and broadening energy activities on campus, with emphasis on conducting research to answer questions or illuminate energy issues. Energy Laboratory research projects this year involve about 100 research staff, 70 faculty, and 250 students from most of MIT's academic departments. Graduate and undergraduate students are an integral part of the interdisciplinary research teams working on both fundamental and mission-oriented projects that address both technical and socioeconomic aspects of important energy issues.

The Energy Markets, Pricing, and Regulation program conducts research on the interaction between energy markets and the macroeconomy, and reviews and evaluates important energy market and environmental policy analysis models.

Current research is directed toward developing and implementing a model of energy and economy interactions for Egypt, and to evaluating the Environmental Protection Agency's Advanced Utility Simulation Model — a large-scale computer model used to analyze national air quality policies.

The Center for Energy Policy Research is organized to conduct policy research, and to contribute to improved domestic and international energy policy making through publications and conferences. Current Center research programs include industry organization and regulation, with emphasis on electric utilities; international energy markets (especially oil and natural gas markets); studies of energy demand, productivity, and economic growth; developing new methods of project and contract evaluation; and energy technology assessment. The Center's research programs are supported by corporations, governments, and noncorporate interest groups. These Associates participate in conferences to discuss the Center's research and to work on topical energy policy issues. The work of the Center is done by faculty and students from several MIT departments, particularly the School of Management and the Department of Economics, and by professional staff members from the Energy Laboratory.

The Energy Engineering program focuses upon research in the engineering sciences needed to enhance energy use in technical industries. Active research areas include thermal plasma materials processing, automated welding, engineering analysis and design methods, and fracture mechanics/fracture control. The research aim is to bridge the gap between the science base and existing industrial practice by providing methods, models, and data that will allow for improvement in technical products and processes.

The Combustion Research Facilities program emphasizes parallel modeling and experimental investigations of combustion processes of gaseous, liquid, and solid fuels in both steady and unsteady operation. A special feature of the experimental studies is that fundamental flame data are obtained in large-scale pilot plant combustors in which the combustion-heat transfer processes closely simulate industrial practice.

Research in the High-Temperature Reactions and Health Effects program concentrates on the oxidation and pyrolysis of fuels and on techniques for controlling emissions from these processes. Studies of the formation of mutagens in hydrocarbon combustion involve a team effort among engineering, analytical chemistry, and biological sciences.

The Synthetic Fuels Center focuses on research on conversion of primary energy resources to liquid and gaseous fuels. Energy companies cooperate to support and offer guidance to the program. Current projects cover a broad range of activities — investigating the comminution of energy minerals, dissociative adsorption of small molecules, coal pyrolysis, and gas desulfurization.

The Transportation Propulsion program conducts research on both improving existing engines and developing new concepts. Activities are based in the Sloan Automotive Laboratory and include fundamental and applied research relevant to internal combustion engines, work on alternative propulsion concepts, and policy and technology studies.

Research in the Environmental program seeks to identify and reduce the environmental impact to energy-related facilities and involves a diverse range of research projects, including cooling systems for electric power plants, water management issues associated with coal development, impacts of acid rain, and local effects of air emissions.

The Electric Utility program serves to inform participating companies about ongoing MIT research activities, to identify and discuss utility needs and priorities, and to develop research projects responsive to those needs. The member organizations currently participating in the program include 18 utilities; 12 other organizations involved in supplying fuel, equipment, or services to the industry; and one government agency.

The Nuclear program has the following broad objectives: 1) to provide direct technical contributions to nuclear plant reliability and safety; 2) to investigate possible improvements in nuclear plant design for more efficient utilization of nuclear resources; and 3) to develop and communicate information to the public and nuclear power industry that will improve the efficient utilization of nuclear power.

The Energy-Efficient Buildings and Systems program examines the behavior of existing buildings and components and seeks to develop new technologies with better energy efficiency. Currently projects include studies of the transfer and accumulation of moisture in structures, air circulation in interiors, new envelope materials, and aging characteristics of closed-cell foam insulation.

The Center for Innovative Mining Systems is a joint program with Pennsylvania State University. It is directed toward coal mining and emphasizes the development of simplified systems suitable for remote control, thereby removing miners from regions of high risk.

Further information about the Energy Laboratory may be obtained by contacting the Headquarters Office, Room E40-455, MIT, Cambridge, Massachusetts 02139 (617) 253-3400.

Undergraduate programs in energy study and research are available in most departments at MIT, including all those in the School of Engineering. These prepare students for careers in the energy field that can be entered immediately upon graduation. Such programs include not only the basic sciences but also the applied sciences, such as fluid and solid mechanics, heat, controls, chemical processes, economics, and materials. Specialized subjects lead more directly toward careers, as in exploration for and production of uranium and fossil fuels; development of alternative energy sources such as solar, wind, and geothermal; petroleum refining; manufacture of synthetic fuels; conventional and nuclear generation of electric power; energy conservation in building, transportation, and manufacturing; and energy policy. In addition, all undergraduate engineering programs provide preparation for graduate work in the field of energy.

Many opportunities exist for undergraduates to work on energy-related research projects offered by the centers, laboratories, and academic departments. This research can be done for thesis or other academic credit or for pay under the Undergraduate Research Opportunities Program. Further information, including lists of advisors, programs, subjects, and research topics related to energy, is available through the Office of the Dean of Engineering, Room 1-206, MIT, Cambridge, Massachusetts 02139.

Graduate programs that prepare students for careers in the energy field are available in all of the Schools at MIT. There are many opportunities for students interested in all aspects of energy science, engineering, management, and policy. While the Energy Laboratory provides a focus for energy research at the Institute, a great deal of energy-related work is also under way in other centers and laboratories, and in the academic departments.

Students interested in graduate work in the energy field should first gain admission to the academic department whose program best matches their background and interests. An individualized program of advanced study and research can be arranged by a balance of fundamental and interdisciplinary subjects that deal with diverse aspects of energy supply, utilization, and policy, and by selection of an appropriate thesis topic. Energy advisors have been appointed in each department to provide information on elective subjects, degree programs, and research opportunities. A brochure containing further information and the list of advisors is available from the Office of the Dean of Engineering, Room 1-206, MIT, Cambridge, Massachusetts 02139.

ESG (Experimental Study Group)

ESG is open to **freshmen and sophomores** interested in participating in a small, informal academic program that offers credit primarily in core subjects through self-paced tutorials, small classes, and study groups. The details of the program can be found in Chapter III, Undergraduate Education. Information can be obtained directly from ESG by contacting Professor J. Kim Vandiver or Holly Sweet, Room 24-612, MIT, Cambridge, Massachusetts 02139, (617) 253-7786.

Health Sciences and Technology

MIT's programs in health sciences and technology are organized within the Harvard-MIT Division of Health Sciences and Technology (HST). The Biomedical Engineering portion of the HST program is described in this chapter. Additional information about HST may be found at the end of the Chapter VII in this catalogue.

Integrated Studies Program

The Integrated Studies Program offers a group of about 60 freshmen and upperclass students an opportunity to link mathematics, science, and engineering subjects to each other and to their social, cultural, and ethical contexts. Freshmen fulfill their General Institute Requirements, and upperclass students complete some of their departmental requirements, while exploring these interrelationships in subjects and seminars offered in ISP. The Program is described in greater detail in Chapter III of this catalogue.

Interdisciplinary Programs in Humanities

The School of Humanities and Social Science offers a number of subjects and programs of an interdisciplinary nature for **undergraduates**. Descriptions of the various interdisciplinary programs can be found under the School of Humanities and Social Science in Chapter VII of this catalogue.

International Food and Nutrition Program

The International Food and Nutrition Program (IFNP), provides an interdisciplinary focus for **postdoctoral** students interested in nutrition field studies, policy analysis, and evaluation of appropriate nutrition interventions.

The Departments of Economics, Political Science, Urban Studies and Planning, and the Anthropology and Archaeology Section of the Department of Humanities also participate. Graduate students are sometimes accepted but must enter through and fulfill all degree requirements of their respective departments. IFNP is affiliated with the Office of International Health of the Harvard School of Public Health. Courses at MIT and Harvard are available to full-time students at either institution.

Representative areas in which IFNP works include the following: a) monitoring the nutritional status of populations, including assessing malnutrition among vulnerable population groups; b) determination of nutrition program benefits; c)interactions among such factors as nutrition, maternal-child health, infection, socioeconomic and cultural characteristics, agriculture policy, and sanitation and other public health problems; d) the effects of income and price changes and of subsidized consumption programs on the nutritional intake of vulnerable populations; e) food and agriculture policies of food-exporting nations as these relate to international food needs; f) international food data systems.

Further information may be obtained from Professor Nevin S. Scrimshaw, Director of the IFNP, Room E38-756, MIT, Cambridge, Massachusetts 02139, (617) 253-5101.

Laboratory for Computer Science

The Laboratory for Computer Science is an interdepartmental laboratory whose principal goal is research in computer science and engineering. The Laboratory includes 16 research groups, currently staffed by approximately 300 faculty, students, and staff members. The academic members of the Laboratory are from the Departments of Electrical Engineering and Computer Science, Humanities, Mathematics, Architecture, and the Sloan School of Management.

The Laboratory for Computer Science was established in 1963 for the advancement of time-shared computer systems. It developed the Compatible Time-Sharing System (CTSS), one of the first time-shared systems in the world, based on pioneering work at what was then the MIT Computation Center. Subsequently, the Laboratory developed Multics, an improved system that introduced several new concepts in time-sharing. These two major developments stimulated research activities in the application of on-line computing to such diverse fields as engineering, architecture, mathematics, biology, medicine, library science, and management. Since that time, the Laboratory's pursuits have expanded, leading to pioneering research in Expert Systems, Computer Networks, and Public Cryptography. The Laboratory is now engaged in a broad front of research activities that span four principal areas: 1) Knowledge-Based Systems; 2) Machines, Languages, and Systems; 3)Theory; 4) Computers and People.

The Laboratory for Computer Science fosters participation in research by undergraduate and graduate students. Research assistantships are available to graduate students for work in all aspects of the research program, and undergraduates may work at the Laboratory under Undergraduate Research Opportunities Program (UROP). Facilities are provided for thesis research and special projects to both graduate and undergraduate students.

Further information may be obtained by contacting Paula Vancini, Room NE43-109, MIT, Cambridge, Massachusetts 02139, (617) 253-5844.

Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 15 faculty and 7 research staff from the Departments of Electrical Engineering and Computer Science and Mechanical Engineering. Disciplines represented include power electronics, automatic control, electromechanics, continuum mechanics, heat and mass transfer, high voltage and insulation research, quantitative physiology, cell biology, systems analysis and economics. Interactions with other Institute and area laboratories contribute to the success of the highly interdisciplinary research that is the style of this laboratory.

Power electronics research ranges from device analysis and fabrication to circuit design and systems development and control. A major current effort involving aspects of all these is aimed at developing a 10 Mhz switching converter and fabricating it in the Microsystems Technology Laboratories. A unique power circuit simulation facility is provided by the MIT Parity Simulator, developed in LEES. Interactions with industry are channeled through the MIT/Industry Power Electronics Collegium. Research is also involved with the modeling, analysis, estimation, and control of electric machines and bulk power systems. Special interest centers on integrating electromechanics, power electronics, and digital/analog signal processing in motors for equipment ranging from appliances to high-performance robots. LEES members are currently completing a 10 MVA superconducting alternator with the Cryogenics Laboratory, which is a major step forward in the development of large-scale generation equipment, as well as a test bed for identifying basic issues concerned with the electrical performance of new classes of materials under conditions of simultaneous electrical, mechanical, and thermal stress.

It is the electrical behavior of gases, liquids, and solids — especially combinations of these — that is the subject of the high-voltage research at LEES. With the objective of understanding micro-discharges in gases and solids and the evolution of charge in liquid dielectrics, electrooptical and digital techniques are being used to shorten the time scale and increase the sensitivity and the spatial resolution with which phenomena can be observed. Applications include pulsed power energy storage, power generation, processing and transmission apparatus, and the development of new materials for capacitors. In one current interdisciplinary project with the Microsystems Technology Laboratory and the Energy Laboratory, micro-discharges, electromechanically induced vibrations, micro-dielectrometry, and chemical sensing are combined with electrical and thermal measurements to discern trends in the operation of transformers and to predict their future performance.

These and other activities involve the discipline of continuum electromechanics. Electrification phenomena associated with electrokinetic processes in liquid dielectrics — used to both insulate and cool transformers and switch-gear — are in this category, as is work on sensors and actuators for deducing electrical, magnetic, mechanical, and thermal parameters and variables in herterogeneous systems.

Work on the continuum electromechanics of cartilage focuses on the role of electrical forces in diseases such as osteoarthritis and on the role of mechanical and electrical forces in the repair of living cartilage. Clinical motivation for work on tissue survival and regrowth under electric stress comes from the treatment of electrical shock victims, while work on electrically controlled transport through polyelectrolyte membranes is aimed at drug delivery systems and protein separations in biotechnology. The effects of environmental electric and magnetic fields on biological systems are being studied over a wide frequency range, including that of electric power systems. The electron beam and other high-voltage radiation facilities have a long tradition of medical applications. These facilities are a resource in promoting physical and chemical processes.

Another discipline activity within LEES is concerned with energy and power systems analysis. Ongoing research projects include the development of new "real-time" or spot-priced-based electric utility tariff structures as well as the development of the algorithms and hardware required by customers to respond to these new tariffs. Additional work is also under way to define integrated energy systems that have greater overall efficiency and are environmentally less harmful.

All programs within the laboratory are carried out with the assistance of both **undergraduate** and **graduate** students under the supervision of faculty members.

Further information may be obtained by contacting the Office of the Director, Professor James R. Melcher, Room 10-172, MIT Cambridge, Massachusetts 02139, (617) 253-4947.

Laboratory for Information and Decision Systems

The Laboratory for Information and Decision Systems is an interdepartmental laboratory for research and education in systems, communications, and control. Computers and computation play an important role in this research. The Laboratory is staffed by over 100 faculty, research scientists, and graduate students principally from the Departments of Electrical Engineering and Computer Science, Mechanical Engineering, and Ocean Engineering. Research falls into three main areas:

1) Research in Communication Science and Systems ranges from studies of the underlying information theoretic properties of networks and point-to-point systems to architectural design. A major research program in this area deals with reliable, efficient communication in data networks. Some of the topics in this program are routing, flow control, the communication complexity of distributed algorithms, contention resolution in broadcast networks, protocols, failure recovery, and topological design. A research program on fundamental aspects of local-area communication networks with optical fiber links has been initiated.

2) Research in Systems and Control Science ranges from fundamental studies in deterministic and stochastic systems, multivariable and adaptive control, nonlinear estimation and statistical signal processing, and large-scale and distributed systems to application areas such as command and control systems and operation and control of complex manufacturing processes. In addition, development of algorithms and special computer structures for estimation, signal processing, computer vision, and control systems are integral parts of this research.

3) Research in Computer and Information Systems is concerned with basic problems in the use of computers in complex information transfer and retrieval systems. One study involves expert intermediary systems to assist end-user access to heterogeneous databases. A second project deals with analytical and experimental investigations of electronic document-delivery networks applicable to interlibrary resource sharing.

The Center for Intelligent Control Systems, established October 1, 1986, is an interuniversity, interdisciplinary center for research in the foundations of intelligent machines and control systems, and is located administratively within MIT's Laboratory for Information and Decision Systems. The Center is operated by a consortium consisting of Brown University, Harvard University, and MIT. Dr. Sanjoy K. Mitter, Professor of Electrical Engineering at MIT, serves as Director of the Center with Professors Roger W. Brockett and Donald McClure, from Harvard University and Brown University, respectively, as Associate Directors. The Center will involve approximately 30 faculty, six postdoctoral students, and 18 Ph.D. students. The research and educational mission of the Center is directed toward the further development of the conceptual and mathematical aspects of the study of intelligent control systems, drawing on relevant work in mathematics, statistics, communications, and computer science, as well as work in control theory itself. Further information about the Center can be obtained from Center Headquarters, Room 35-308, (617) 253-2142.

Research opportunities are available in the Laboratory for both **undergraduate** and **graduate** students. Undergraduates may participate through UROP.

Further information may be obtained by contacting the Offices of the Codirectors, Professor S. K. Mitter, Room 35-304, MIT, Cambridge, Massachusetts 02139, (617) 253-2160, and Professor R. G. Gallager, Room 35-206, (617) 253-2533.

Laboratory for Manufacturing and Productivity

The Laboratory for Manufacturing and Productivity is an interdisciplinary center for education and research in manufacturing and productivity at MIT. The goal of the Laboratory is the advancement of manufacturing science and technology.

The Laboratory educates scientists and engineers in the analysis and synthesis of products, processes, and manufacturing systems. Fundamental research conducted in the Laboratory leads to innovation in manufacturing process technology and better understanding of planning, design, and production operations. The Laboratory seeks to establish a rational foundation for manufacturing based on a systematic understanding of the complex interactions among the many areas of manufacturing including design, processing, assembly, inspection, and quality control.

The Laboratory draws upon faculty and staff in the Departments of Mechanical Engineering, Electrical Engineering and Computer Science, Civil Engineering, Materials Science and Engineering, and Ocean Engineering, as well as the Sloan School of Management. Important perspectives are contributed by the representatives of industrial firms associated with the Laboratory's cooperative research programs.

Current research programs include flexible automation and robotics, polymer processing, tribology, manufacturing quality, manufacturing systems, and manufacturing design integration.

In addition to research projects sponsored by individual organizations, a large proportion of the Laboratory's work is supported by several consortia of industrial firms. Among these are the MIT-Industry Polymer Processing Program and the Tribology Research Program.

Opportunities for **undergraduates** and **graduate** students are available for thesis research and UROP projects. A limited number of postdoctoral research positions are also available.

Additional information may be obtained from the Director, Professor David E. Hardt, Room 35-238, MIT, Cambridge, Massachusetts 02139, (617) 253-2234.

Laboratory for Nuclear Science

Bates Linear Accelerator Center

Center for Theoretical Physics

The **Laboratory for Nuclear Science** performs basic research in nuclear and elementary particle physics. It supports research interests of faculty in the Department of Physics by maintaining and administering facilities adapted to studies in high-energy and nuclear physics. The Laboratory operates the Bates Linear Accelerator Center and the Center for Theoretical Physics. In addition, the Laboratory provides a machine shop, drafting and technical illustration, electronics shop, and a computer facility for staff and students.

As part of the nuclear physics program, members of the Laboratory are engaged in experiments at the Bates Linear Accelerator, the Brookhaven Tandem-AGS Accelerator, and the Los Alamos Meson Physics Facility. The high-energy physics program involves experiments at the CERN in Geneva, Switzerland, the Fermi National Accelerator Laboratory, the Stanford Linear Accelerator, and at the Gran Sasso Laboratory in Italy.

Among many projects are theoretical studies of nuclei and elementary particles; experimental programs using a variety of detector techniques to study strong, electromagnetic, and weak interactions of elementary particles and other high-energy phenomena; application of high-speed electronic computer techniques to the problems of nuclear and elementary particle data analysis; nuclear studies using heavy-ion accelerators; and programs in medium-energy nuclear research with electrons, photons, protons, and pions.

Students participate in the entire range of research programs in fulfilling their **graduate** and **undergraduate** degree requirements or as participants in UROP.

Further information may be obtained from the Office of the Director, Professor Arthur Kerman, Room 26-505, MIT, Cambridge, Massachusetts 02139, (617) 253-2395.

The William H. Bates Linear Accelerator Center, funded by the US Department of Energy for use by MIT research staff (principally in the Laboratory for Nuclear Science and the Department of Physics), is available for use through a formal users' organization to qualified researchers nationwide.

The Laboratory supports a broad program of research in electromagnetic interactions with nuclei. Facilities are available for high-precision/high-resolution electron scattering, photoreactions including pion production, and coincidence studies. The maximum electron energy available is 1 GeV. A polarized electron source makes possible studies of parity violation in electron scattering and spin effects in nuclear reactions. A storage ring is under construction and, upon completion, will provide high-duty factor beams and a novel internal target capability.

The research participation of physics students, as **undergraduate** laboratory assistants working on UROP projects and through **graduate** thesis work, is encouraged and forms an important part of the Bates program. A large number of students, from the universities of user physicists as well as from MIT, are so involved. Further information may be obtained from the Director, Professor E. J. Moniz, Room 26-567, MIT, Cambridge, Massachusetts 02139, (617) 253-6202.

Laboratory of Architecture and Planning

The Laboratory of Architecture and Planning (LAP), part of the School of Architecture and Planning, fosters research contributing to the understanding, education, and practice of architecture, planning, real estate development, and closely related fields.

Projects currently administered by the Laboratory focus on energy conservation and appropriate technology; development of techniques for assessing the environmental impacts of development and for mediating disputes concerning such developments; solar architecture; neighborhood and community development; use of media as a tool for public participation in community planning; building technology and building assessment.

The LAP provides a range of continuing educational opportunities for the architectural and planning professions. The Laboratory also promotes the integration of research into the educational environment of the school and the Institute through the sponsorship of lectures, seminars, and conferences; publication support; and a program of architecture case studies. The LAP's activities are worldwide.

The Laboratory involves a wide variety of people and institutions both inside and outside MIT, including faculty and students from MIT departments and centers, as well as from other educational institutions; the alumni of the School of Architecture and Planning; architectural and planning practitioners; and client groups such as firms, public agencies, and community organizations. LAP research involves **graduate** and **undergraduate** students from several MIT departments, through research assistantships and UROP.

Further information may be obtained from the Office of the Director, Michael Joroff, Room 4-209, MIT, Cambridge, Massachusetts 02139, (617) 253-1350.

Law-Related Studies

Undergraduate and **graduate** students interested in the legal or public policy aspects of their field or the legal profession in general, may participate in a wide range of undergraduate or graduate subjects. Among the over 30 law-centered subjects in 10 departments are syllabi covering the American legal structure, the judicial process, constitutional history, and legal aspects of planning, management, environmental affairs, ocean resources, construction, transportation, industrial safety, computer science, and technology.

In addition to several lawyers on the teaching staffs of many different departments, there are lawyers on the administrative staff who are willing to share their experiences with students. Many of these individuals are members of the Pre-Law Advisory Council, and are pleased to assist students interested in the legal profession. MIT undergraduates from nearly every department have gone on to law school. The technically oriented undergraduate training serves students well in law school and in future practice. Law schools are very eager for MIT applicants.

The Office of Career Services and Preprofessional Advising, Room 12-170 and Room 12-185, (617) 253-4737, and members of the Pre-Law Advisory Council provide guidance and information for students interested in going to law school. The Chairman of the Council is Professor J. D. Nyhart. All students interested in a legal career should phone or come by the office for information regarding law-related studies at MIT.

Leaders for Manufacturing Program (M.S.)

The Leaders for Manufacturing Program is a 24-month double master's degree program beginning in June of each year, open to incoming graduate students planning a career in manufacturing companies. Offered jointly through the School of Management and five departments in the School of Engineering (Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, and Mechanical Engineering), the program also involves close cooperation with nine manufacturing companies, including on-site research. It focuses on holistic engineering and management by integrating the management and engineering disciplines, and by emphasizing teamwork, systems optimization, the management of change processes, and learning by doing.

The rigorous curriculum, including projects, off-campus research, seminars, and classroom work, is developed and taught by faculty from both Schools. The coursework and research culminate in a single thesis leading to a Master of Science degree in both Engineering and Management.

Application material is available only through the Program office and is due back in that office by February 1. Applicants must meet the requirements for admission to both the School of Management and a participating department in the School of Engineering. All applicants must take the GRE and GMAT, and all foreign applicants must submit scores from the TOEFL.

Application material and complete information of Program objectives and the curriculum are available from the Program office, Room 9-319, MIT, Cambridge, Massachusetts 02139, (617) 253-1055.

Lincoln Laboratory

The Lincoln Laboratory is a Federally sponsored center for research and development in advanced electronics, with special emphasis on applications to national defense. The Laboratory is staffed and operated by MIT and located in Lexington, Massachusetts.

Lincoln Laboratory activities extend from fundamental investigations in science, through technological development of devices and components to the design and development of complex systems. A continuing program of research in advanced electronics techniques provides a background of experience and ideas for work in specific programs, as well as a source of new scientific and technological advances for civilian and military application.

Specific programs include satellite communications, reentry studies and technology, computer systems and digital signal processing, image processing, space surveillance, and air traffic control. Research also is conducted in the fields of optics, solid-state devices, radar systems, and machine intelligence.

Opportunities for research in many of these technical areas are available to MIT faculty members and qualified **undergraduate** and **graduate** students. Inquiries may be directed to Mr. Alan A. Grometstein, Assistant to the Director, LIN A-163, (617) 981-7024, or Institute extension 181-7024.

Management of Technology Program (S.M.)

This is a 12 month executive education program leading to the degree of Master of Science in the Management of Technology, aimed at meeting the growing worldwide demand for managers who can help bring advances in technology to the marketplace in the form of new products and manufacturing processes. It is designed for men and women with engineering or science backgrounds — and five to ten years of technical work experience — who wish to learn to understand, develop, and manage both the new and established technological resources of public and private organizations in a global economy of rapid change. Offered jointly by the MIT Schools of Engineering and Management, this is the nation's first advanced degree program focusing directly on the management of technology.

The rigorous curriculum, developed and taught by faculty from both Schools covers three elements: 1) underlying core subjects in management and analytic methods, 2) in-depth studies on management of technical programs and organizations, and 3) a thesis relating to the management of technical programs and organizations. Participating departments include the Sloan School of Management and all eight departments in the School of Engineering.

Application material is available only through the program office and is due back in that office by February 15. All applicants must take the GMAT and all foreign applicants must submit scores from the TOEFL.

Application material and complete information on Program objectives and the curriculum are available from the Program Office, Room E52-125, MIT, Cambridge, Massachusetts 02139, (617) 253-3733.

Materials Processing Center

The Materials Processing Center (MPC) transcends the traditional academic boundaries to provide an interdisciplinary focus on the processing and performance of materials. The MPC's founders realized that the properties of all types of materials arise from their structure — from the manner in which their constituent atoms aggregrate into crystalline arrays or into disordered amorphous structures. A recurring theme through all MPC research is, therefore, the interrelationships of structure-properties-performance through processing control.

To develop and expand the fundamental scientific and technological base of materials processing, the MPC follows a three-pronged approach with programs in interdisciplinary research, education, and technology exchange.

Fragments of many basic yet critical materials processing problems are studied in normally isolated academic departments. To bridge these divisions and focus research on a processing problem as a whole, the MPC coordinates faculty expertise and facilities from a number of MIT departments, principally Materials Science and Engineering, Chemistry, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemical Engineering. MPC research incorporates all engineering materials including metallic, ceramic, polymeric, and electronic materials.

The MPC uses two educational programs to attract outstanding students to the study of materials processing. Special summer scholarships bring exceptional **undergraduate** students from across the country to MIT to participate in ongoing materials research projects. MPC awards fellowship appointments to outstanding first-year **graduate** students investigating some aspect of materials processing. Other graduate students are supported by research programs funded by grants and contracts through the MPC. The MPC also conducts continuing education programs to help keep professional engineers and scientists abreast of recent technological information.

The MPC builds upon the strong links that MIT has traditionally had with both industry and government. Through the Industry Collegium, the MPC provides a forum for industrial representatives to discuss their needs and problems with researchers in the university. Each year, the MPC sponsors symposia on a variety of materials processing topics to encourage the flow of information on recent scientific and technological developments between the university and industry. The MPC also encourages and sponsors the appointments of industry and government personnel as visiting faculty, adjunct faculty, and postdoctoral researchers.

For more information, contact Professor R. M. Latanision, Director, Room 8-202, (617) 253-4697 or 253-5463, or Dr. G. B. Kenney, Assistant Director, Room 12-007, 253-3244, MIT, Cambridge, Massachusetts 02139.

Media Laboratory

The Media Laboratory addresses the quality of life in an electronic age by focusing on the invention and creative use of modern media. "School of the Future," "Movies of the Future," synthetic holography, computer music, computer animation, electronic publishing, and advanced typographics are examples of ongoing research programs, all of which address one or more aspects of a future, high-quality, human-like interface between people and machines.

The Laboratory is largely funded by industry, including founding companies that helped finance MIT's new Wiesner Building, in which the Laboratory is housed. The research groups enjoy MIT's densest population of new and advanced computing resources, including a massively parallel supercomputer, five mainframes, 55 high-end workstations, and over 250 personal computers. The facility includes a 200,000 cubic foot experimental media facility for large-scale and performing arts experiments. The Laboratory provides a collaborative and exchange program with Japanese industry and academia.

Research at the Media Laboratory is tightly coupled with the degree programs in Media Arts and Sciences, a description of which can be found under the School of Architecture and Planning. All incoming students are eligible for full-time research assistantships. Faculty affiliated with the program believe that there is a unique discipline in the making at the intersection of the communication and cognitive sciences.

Middle East Program

The Middle East Program at MIT is an interdisciplinary course of study taken in conjunction with the **graduate** program in a student's chosen department. The focus is on technology, development, and public policy. Its purpose is to enable students with an interest in the Middle East to develop an expertise in the area, within the context of a coherent program of study. The program is designed to equip students with an understanding of the processes of socioeconomic change, technological development, political change, institutional development, and business and investment patterns in the region.

This program draws on MIT's unique strength in the areas of science and technology to offer a course of study distinct from a conventional "area studies" approach to the Middle East.

The Program is based on the participation of faculty from the Departments of Political Science, Civil Engineering, Economics, and Urban Studies and Planning; the History Section of the Department of Humanities; the Sloan School of Management; the Program in Science, Technology and Society; and the Aga Khan Program in Islamic Architecture. Further information is available from Professor Nazli Choucri, Department of Political Science, Room E53-493, MIT, Cambridge, Massachusetts 02139, (617) 253-6198.

Mining and Mineral Resources Research Institute

Mineral Resources Engineering and Management (S.M., Eng., Ph.D)

The **Mining and Mineral Resources Research Institute** (MMRRI)was founded to support and aid in the coordination of the wide variety of academic activities and research programs related to mineral resources. In particular, it encourages interdisciplinary activities for **graduate** students and calls attention to opportunities for careers in mineral resource engineering and management. The direct support of the MMRRI, which comes from the US Department of the Interior, includes funding for a limited number of fellowships and scholarships and for some research activities.

The Departments of Civil Engineering; Mechanical Engineering; Materials Science and Engineering; Earth, Atmospheric, and Planetary Sciences; Ocean Engineering; Economics; Management; and Political Science are involved, as is the Energy Laboratory. Some of the major problems being addressed are finding mineral resources, extracting and processing them economically and in an environmentally acceptable manner, and reducing our need for mineral resources and substituting one resource for the other. Undergraduate and graduate interdisciplinary programs of study in Mineral Resources Engineering and Management (described later), represent the academic side of the MMRRI.

Information on the various activities of the Mining and Mineral Resources Research Institute and on departmental advisors and special programs of study may be obtained from the Office of the Director, Professor John F. Elliott, Room 4-138, MIT, Cambridge, Massachusetts 02139, (617) 253-3305.

The Mineral Resources Engineering and Management (S.M., Eng., Ph.D.) program provides formal educational opportunities to **graduate** students with interests in the mineral resources field. The academic subjects and research available throughout the Institute make it possible to offer programs in several areas of concentration, leading to a variety of careers in the mineral resources field. Studies in the MREM program can lead to the Engineer, Ph.D., or Master of Science corresponding to the department of registration.

The MREM program consists of four subprograms: 1) The exploration subprogram exposes students to the geological, technical, and decision theoretical aspects of exploration. 2) The extraction subprogram provides a background for design of surface or underground mines, selection and development of mining machinery, management of large projects, and resolution of environmental problems. 3) The processing subprogram deepens the student's physical and chemical education and leads to the analysis and design of industrial processes including their managerial and environmental aspects. 4) The resource management subprogram encompasses a wide range — systems engineering, economics, and public policy — as well as problems of substitution and of related resources (water, energy). Emphasis in the resource management subprogram can be placed on engineering, management, or public policy. The resource management subprogram also provides an MREM general overview, aimed at students desiring a broader education.

For the Master of Science degree, a student usually will take at least 75 percent of the required credit units from one of the subprograms and the remaining credit units from one of the other subprograms. Engineer and Ph.D. students usually will concentrate at least half of their credit units in one of the subprograms and take the remaining credit units from at least two of the other subprograms. Research projects suitable for thesis work are conducted in most of the participating departments (Urban Studies and Planning; Civil Engineering; Chemical Engineering; Mechanical Engineering; Materials Science and Engineering; Ocean Engineering; Earth, Atmospheric, and Planetary Sciences; Economics; Political Science; Sloan School of Management).

Students desiring to pursue their studies in the MREM program should apply for admission to graduate studies in the department best suited to their interests. Students will be awarded the graduate degree in this department.

A prospectus containing detailed information on the MREM program, including listings of academic subjects in each of the subprograms, possible research areas, and the MREM faculty contacts in each of the participating departments, may be obtained from Professor Herbert H. Einstein, Room 1-330, MIT, Cambridge, Massachusetts 02139, (617) 253-3598.

MIT-Japan Science and Technology Program

The MIT-Japan Science and Technology Program was created in 1981 to establish MIT as a leader in educating American scientists and engineers about Japan. An associated goal is to facilitate collaborative research among Japanese and American scholars. Both aims are accomplished through the development of three areas of integrated activities — education, research, and public service — in the US as well as in Japan. The Program is administered by the Center for International Studies at MIT and is open to any **undergraduate** or **graduate** student. Students usually enroll in the program after completing their degree requirements, but can enter at any time.

The Program provides internships to science and engineering students who have acquired Japanese language capabilities and a cultural understanding of the country. A student is sent to Japan only after having the equivalent of two years of training in the Japanese language through credit or noncredit study. Students also must attend orientation seminars on Japan. The Program trains and supervises the placement of 15 to 20 students each year. Some of the private firms that have hosted these interns are Toshiba, Nippon Electric Company (NEC), Matsushita, and Hitachi. Other interns have studied at the Faculty of Engineering at Tokyo and Kyoto Universities, as well as at national laboratories.

Joint research efforts at MIT under the auspices of the Program include an exchange program, funded by the Japanese government, for international energy policy studies in the Energy Laboratory and Center for International Studies. The Sloan School of Management, the Energy Laboratory, the Laboratory for Architecture and Planning, and the Bitter National Magnet Laboratory participate in various research projects with Japanese scholars and practitioners. In addition, the Program has supported research in Japanese linguistics for Project Athena and a study of the management of research and development in Japanese computer firms.

In the public service area, the Program sponsors several workshops and symposia in its effort to keep American government and industry abreast of Japanese scientific and technical developments.

Further information may be obtained from Ms. Patricia Gercik in the Office of the Director, Room E38-656, MIT, Cambridge, Massachusetts 02139, (617) 253-3142.

Nuclear Reactor Laboratory

The Nuclear Reactor Laboratory (NRL) provides the focus for a wide range of research programs that involve the use of nuclear radiations. Research programs in various MIT departments and centers — including Physics; Materials Science and Engineering; Earth, Atmospheric, and Planetary Sciences; Chemical Engineering; Mechanical Engineering; Nuclear Engineering; and the Program in Toxicology in the Whitaker College — are supported by the capabilities in the NRL. Facilities of the Nuclear Reactor Laboratory are also used for teaching and research activities by other institutions. The NRL provides special services to regional hospitals and industries, e.g., short-lived isotopes for medical purposes.

Current areas of research include applications of nuclear trace analysis to problems in the physical and engineering sciences, life sciences, geosciences, and the environment; neutron and nuclear physics; neutron scattering studies of solids, liquids, and dense gases; radiation effects on materials; bulk and near surface radiation damage studies of nuclear and fusion reactor materials; reactor physics; dose reduction in power reactors and reactor engineering; nuclear medicine; and isotope development.

The NRL operates a 5-million watt research reactor (MITR-II), which is one of the largest university reactors. Recent redesign and rebuilding of MITRE-II has significantly enhanced the neutron and gamma-ray intensity and the reactor's versatility.

Experimental facilities and instrumentation at the NRL include neutron diffractometers; 2- and 3-axis, polarized beams, spin flippers; neutron inelastic scattering spectrometers; a neutron interferometer; magnetic and cryogenic sample control; a wide variety of sample irradiation facilities with fast and slow neutron fluxes up to 10^{14} per cm^2 and sec; a temperature-controlled in-pile facility that allows simultaneous neutron and ion bombardment; and a fast reactor blanket facility.

Other experimental facilities and instrumentation include a thermal column with large hohlraum; radiochemistry laboratories; hot cells for dismantling or testing; nuclear detection equipment; trace analysis facilities; a materials characterization laboratory; and shielded hot cells for handling and testing radioactive materials.

Undergraduate students are involved in the operation of the reactor and in the research activities through special projects or senior theses. Graduate student thesis research is carried on in the various research areas mentioned earlier.

A current summary report is available and describes the activities at the NRL in greater detail. For information, inquire at the Office of the Director, Professor Otto K. Harling, Room NW12-208, MIT, Cambridge, Massachusetts 02139, (617) 253-4201 or 253-4202.

Oceanography and Oceanographic Engineering (Eng., Ph.D., Sc.D.)

MIT and the Woods Hole Oceanographic Institution (WHOI) on Cape Cod offer joint programs of graduate study and research for students with special interests in biological oceanography, chemical oceanography, marine geochemistry, marine geology, marine geophysics, oceanographic engineering, and physical oceanography. These graduate programs are administered by committees drawn from the faculty and staff of both institutions. Students accepted to the Joint Program have access to the extensive intellectual and physical resources available for advanced study at both WHOI and MIT. The program is described in detail at the end of Chapter VII.

Operations Research Center

Operations Research (S.M., Ph.D.)

The Operations Research Center (ORC) provides educational and research opportunities for students and faculty interested in the interdisciplinary field of operations research. Operations research is concerned with conceptualizing and implementing mathematical models for analyzing planning and operating problems arising in the public and private sectors. Generally speaking, these are normative models that are optimized to provide decision makers with better insights into their decision problems and to assist them in selecting the most effective courses of action.

The Operations Research Center is organized as an interdepartmental center, structured to take advantage of the expertise of faculty drawn from a variety of departments, including the Sloan School of Management, Electrical Engineering and Computer Science, Aeronautics and Astronautics, Mathematics, Civil Engineering, Ocean Engineering, Urban Studies and Planning, and Nuclear Engineering. The ORC is composed of approximately 30 affiliated faculty and 50 graduate students. Both a master's and a doctoral degree program are offered. An important feature of these programs is their interdisciplinary structure. In addition to following a set of core courses, students are encouraged to design a curriculum that is tailored to their professional and research interests. The program provides a strong background in the theoretical foundations of operations research and the practical techniques used in building models for a wide variety of applications. The ORC provides a range of micro-, mini-, and mainframe computer facilities, with associated software, for model building and algorithmic experimentation

The core graduate curriculum for both S.M. and Ph.D. degrees consists of Applied Probability (6.431), Decision Analysis (15.065), Applied Statistics (15.075), and Introduction to Mathematical Programming (15.081J/6.251J). Master's degree students continue with three additional graduate-level subjects and prepare a thesis in an area of research concentration. Employment opportunities for graduates of the S.M. program exist in technical staffs of private firms, often in the services sector of the economy, as planners in governmental agencies, and in private consulting firms.

Doctoral degree students are expected to take, in addition to the core subjects, Discrete Event Stochastic Processes (6.262), Statistical Modeling and Data Analysis (15.076J/18.457J), Network Optimization (15.082), Combinatorial Optimization (15.083), Nonlinear Programming (15.084J/6.252J), and Analysis (18.100). Doctoral degree candidates must qualify for continuation in the program by passing Qualifying and General Examinations which are taken in the first and second years of a typically four-year program. Coursework in a minor program follows, in addition to pursuing an original research project under the guidance of a doctoral dissertation committee. The formal academic program is supplemented by teaching and research assistantship opportunities for most doctoral candidates. Graduates of the Ph.D. program often assume faculty or consulting positions in the US and abroad.

Students wishing to concentrate specifically in operations research at either the master's degree or doctoral degree level may apply directly to the interdepartmental graduate program. This can be done by following general MIT graduate admissions procedures and by inserting, "Operations Research — Interdepartmental Program," in all places on the application materials requesting a departmental designation.

Further information about the Operations Research Center and the degree programs is contained in a brochure entitled *Graduate Education at the Operations Research Center* and is available from the Operations Research Center, Webster Building (E40-164), MIT, Cambridge, Massachusetts 02139. Individual questions may be addressed to either of the Codirectors, Professors Thomas L. Magnanti and Amedeo R. Odoni, or to Marcia V. Chapman, Assistant Director.

Plasma Fusion Center

The Plasma Fusion Center, formed in 1976, provides a focus for experimental and theoretical studies in plasma fusion physics and related engineering disciplines. It provides the leadership required for effectively undertaking all Department of Energy sponsored fusion research at MIT. The timely development of fusion energy is one of the most technically complex challenges facing society.

The Plasma Fusion Center fosters independent creativity, and helps integrate the collective fusion activities into a cohesive program with the following broader Institute goals:

— to provide, both nationally and internationally, strong technical leadership for the development of fusion energy;

— to provide the intellectual environment for the expert educational training of students, research scientists, and engineers.

Fusion research activities at the Plasma Fusion Center fall into six major programmatic divisions.

The Fusion Systems Division is concerned with overall design and reactor physics investigations of the next generation of major toroidal and mirror fusion devices; understanding the potential characteristics and technology requirements of power-producing fusion reactors; and developing new reactor design concepts and advanced plasma diagnostics using both active and passive measurements of electromagnetic radiation.

The Advanced Concepts Division has developed an increased understanding of basic tandem mirror physics with emphasis on stability properties, thermal barrier formation, and RF heating.

The Fusion Technology and Engineering Division aims to provide critical engineering support for operating confinement experiments and advanced design projects. It also develops advanced high-field copper magnet technology and superconducting magnet technology for the national fusion program.

The Applied Physics Research Division is developing the basic experimental and theoretical understanding of plasma heating and confinement properties, including research on tokamak and mirror systems, advanced fusion concepts, fusion theory and computations, and diagnostics and laser development.

The Toroidal Confinement Experiments Division is developing a basic understanding of the stability and transport properties of high-temperature toroidal plasmas at reactor-level conditions and developing and testing concepts for optimization of the toroidal confinement approach to magnetic fusion. The subprogram areas include the ALCATOR C-MOD tokamak facility, which is now under construction.

The Coherent Electromagnetic Wave Generation Division is developing a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in the 1 μm to 1 cm range. Particular emphasis is being placed on the development of free electron lasers, cyclotron masers (gyrotrons), and novel radiation sources.

In the last decade, many results of great significance to the international effort to develop fusion energy have been obtained in the ALCATOR A and C high-field tokamaks, the major experimental facilities in the Plasma Fusion Center Program. For example, ALCATOR C established a world record in obtaining the highest product of plasma density times confinement time, and was also a world leader in developing techniques to drive current by radio-frequency waves. VERSATOR II and CONSTANCE are used to study particular research aspects of toroidal and mirror-confined plasmas, respectively. The overall program has a balance between experimental and theoretical studies. Fusion activities in the Departments of Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics, as well as the Francis Bitter National Magnet Laboratory and the Research Laboratory of Electronics, are affiliated with the Plasma Fusion Center.

The Center's programs provide an excellent forum for the training of students and professional researchers. Approximately 75 graduate students and 15 undergraduate students are currently involved at all levels of thesis work; undergraduates also participate through UROP.

Further information may be obtained from the Office of the Director, Professor Ronald R. Parker, Room NW16-202, Cambridge, Massachusetts 02139, (617) 253-5553.

Power Engineering

Interdepartmental academic and research programs in power engineering are available in the Departments of Aeronautics and Astronautics, Electrical Engineering and Computer Science, Mechanical Engineering, Ocean Engineering, and Nuclear Engineering. These programs cover a broad range of energy-related issues. Research is conducted at the Gas Turbine Laboratory, Laboratory for Electromagnetic and Electronic Systems, Sloan Automotive Laboratory, Energy Laboratory, Heat Transfer Laboratory, Cryogenic Engineering Laboratory, and at the Nuclear Reactor.

A graduate student enrolled in any of the above departments may construct from among various subject offerings and research activities an academic program and thesis research. In addition to subjects treating specific topics in power engineering, many other related subjects are available on such topics as thermodynamics, fluid mechanics, heat transfer, control theory, materials, stress analysis, vibrations, cryogenics, and combustion.

Research assistantships are available for graduate students, and some part-time employment is available for undergraduates. For further information on the programs and on financial support, contact the Graduate Registration Officer of one of the participating departments.

Program in Polymer Science and Technology (PPST)

The Schools of Engineering and Science have established a graduate program in polymers. It is open to qualified students admitted to the graduate program of any MIT department. It consists of an initial academic phase in which all students participate (regardless of previous background and research interest), followed by research in a selected area of specialization. The program leads to the doctoral degree; if desired, a master's degree can be obtained through the student's department.

The core curriculum, taken by all students, provides a common base in the field of polymers. It is broad, rigorous, and covers both elementary and advanced subjects spanning the entire range from the molecular level to the continuum. This curriculum takes up the first two semesters in the graduate program.

The transition from the academic phase to research is marked by the qualifying exam, which consists of both oral and written sections. The exams are offered at the end of each spring term and are based on the PPST core curriculum. Successful completion of the exam leads to selection of a research project and the preparation and defense of a thesis proposal.

Any faculty member at MIT can act as a research supervisor. The thesis supervisor(s) advises the graduate student on a continuing basis throughout the time of the research project. Completion and successful defense of the thesis before PPST and departmental faculty fulfill the requirements for the doctoral degree.

For more information on this program, including details of admission and financial aid procedures, contact Professor Fred McGarry, Director, Program in Polymer Science and Technology, Room E19-356, MIT, Cambridge, Massachusetts 02139, (617) 253-3115.

Programs for Double Competence in Humanities/Social Science and Science/Engineering

At MIT there are several ways for an undergraduate student to achieve intellectual "dual literacy" or "double competence," an education that includes study in depth in both Humanities/Social Science and Science/Technology areas: 1) double majoring, which brings two S.B. degrees; 2) joint majoring, which combines disciplines from both areas in a single degree program — Course XXI-E (Humanities and Engineering) and XXI-S (Humanities and Science); 3) a degree in a science or engineering discipline, complemented by a minor program in a Humanities, Arts, or Social Science field.

Further information may be obtained from Professor Philip S. Khoury, Associate Dean, School of Humanities and Social Science, Room E51-230, MIT, Cambridge, Massachusetts 02139, (617) 253-2601 or 253-4443.

Research Laboratory of Electronics (RLE)

Established in 1946 as the Institute's first interdepartmental laboratory, the Research Laboratory of Electronics provides faculty members and their students, both graduate and undergraduate, with the diverse services and facilities of a large laboratory to conduct research in two major areas — electronics and optics — together with language, speech, and hearing. In addition, smaller groups are focused on atomic and molecular physics, plasma physics, radio astronomy, digital signal processing, image processing, electromagnetics, and communications. Participants come primarily from the Departments of Electrical Engineering and Computer Science, Physics, Chemistry, Materials Science and Engineering, and Linguistics and Philosophy.

Research in electronics and optics covers a broad spectrum of concerns ranging from electronic materials and fabrication through high speed electronic and optic devices to electronic and optical circuits and, finally, logic, architecture, and large-scale systems. RLE brings together fundamental theoretical and experimental work in the nature of materials and surface interfaces with practical devices, circuits, and systems oriented to high-performance applications.

The program in language, speech, and hearing includes linguistic work in phonology coupled with the structure and design of systems for text-to-speech conversion and speech recognition, as well as fundamental work on articulatory phonetics, sensory communication, and auditory physiology.

Additional research foci include fundamental studies in atomic, molecular, and optical physics such as radiation modes and basic constants, theoretical and experimental research in plasma physics, radio astronomy and astrophysics, digital signal processing theory and hardware architecture, digital processing of two-dimensional signals (including high-resolution television), studies of electromagnetic propagation in nonlinear media, and a variety of studies in communications including structure and protocols for high-speed local networks.

Almost all research in RLE is conducted or supervised by academic faculty members and students. Approximately 60 faculty members are affiliated with RLE. They work with over 300 graduate students and approximately 100 undergraduates, in addition to research staff. The research in RLE provides opportunities for a broad spectrum of student thesis projects.

Additional information may be obtained by contacting the Office of the Director, Professor Jonathan Allen, Room 36-413, MIT, Cambridge, Massachusetts 02139, (617) 253-2509.

Science, Technology, and Society

The Program in Science, Technology, and Society (STS) focuses on the ways in which scientific, technological, and social factors interact to shape modern life. It traces the impact of scientific ideas and technological practices on society and culture and examines the role of social, political, and cultural considerations in shaping developments in science and technology. STS draws its faculty from the social and natural sciences, engineering, and the humanities. Various opportunities for research and study are available at the undergraduate and graduate levels. A more detailed description of the Program is given in the School of Humanities and Social Science section in Chapter VII. Further information may be obtained from the Office of the Director, Professor Kenneth Keniston, Room E51-110, MIT, Cambridge, Massachusetts 02139, (617) 253-4062.

Sea Grant College Program

The MIT Sea Grant College Program funds and coordinates multidisciplinary research, educational programs, and advisory services to further develop ocean and coastal resources. Following the lead of the National Sea Grant Program, created by Congress in 1966, MIT recognized that science and engineering should play vital roles in advancing our use of the oceans. The designation of the Institute in 1976 as the nation's 12th Sea Grant College, strengthened its existing programs of ocean research and education. Today, with Sea Grant Support, MIT expertise and facilities are regularly used to solve technological, social, economic, and political problems associated with marine resource utilization and coastal zone development.

Sea Grant research strives for balanced use of oceans and coasts, greater harvests of food and useful materials from the sea, the prudent extraction of offshore oil and undersea minerals, and the application of engineering to improved methods of working in and on the seas. At present, the principal departments involved in Sea Grant research include Civil Engineering, Mechanical Engineering, and Ocean Engineering. Students participate directly in most Sea Grant research projects at both graduate and undergraduate levels, and support is available for UROP projects.

The Sea Grant Program also supports innovative education at MIT in ocean use and coastal zone development. The Program has supported new curricula and textbooks in the field of ocean engineering. A joint project with the Massachusetts Maritime Academy is providing new educational opportunities for professional fishermen.

MIT Sea Grant's Advisory Services publish technical reports, sponsor symposia, and work with local governments, businesses, and organizations to transfer comprehensive information to the public on the many facets of resource development in the oceans and coastal zones. Joint research programs, conducted with related businesses and industries, assure the efficient and timely dissemination of new technologies and research results.

For more information on Sea Grant Program projects and services, contact the Office of the Director, Professor Chryssostomos Chryssostomidis, Room E38-302, MIT, Cambridge, Massachusetts 02139, (617) 253-7041.

Spectroscopy Laboratory

The George Russell Harrison Spectroscopy Laboratory is dedicated to advancing knowledge of the structure and dynamics of atoms and molecules and the properties of liquids, solids, and biological materials utilizing the techniques of modern spectroscopy. These techniques include the use of lasers, signal processors, computers, and electrooptic devices. The Spectroscopy Laboratory encourages participation and collaboration among staff members in various

disciplines of science and engineering. At present, several departments (principally Chemistry, Physics, Biology, Electrical Engineering and Computer Science, and the Harvard-MIT Division of Health Sciences and Technology) are involved. In addition, scientific visitors from the US and abroad participate in the work of the Laboratory.

Current research areas include high-resolution laser spectroscopy of excited vibrational and electronic molecular levels, CARS studies, kinetics of intermediates in organometallic complexes, laser optical pumping of atoms, infrared and optical double resonance experiments, laser saturation spectroscopy, coherent transients, photon echoes, laser-nuclear spectroscopy, superradiance, Rydberg atoms, structural studies of biological molecules using Raman techniques and X-ray diffraction data, technical holography, and applications of lasers in medicine.

The Laboratory houses two resource centers. The MIT Laser Research Center, supported by a grant from the National Science Foundation, is devoted to physical science research. The Laser Biomedical Research Center, supported by a grant from the National Institutes of Health, is devoted to biomedical research. The two centers make available to researchers from various university and industrial research institutions one of the most extensive collections of lasers for spectroscopic research in the US. Facilities include excimer and Nd; YAG-pumped pulsed dye lasers, Ion laser-pumped CW dye lasers, picosecond lasers, CW and pulsed CO_2 lasers, pulsed and CW Raman spectrometers, microcomputers, and auxiliary signal processing equipment.

Many graduate and undergraduate students perform thesis research in the Laboratory; UROP projects are offered in many areas of laser research.

Further information on the Laboratory may be obtained from the Office of the Director, Professor Michael Feld, Room 6-014, MIT, Cambridge, Massachusetts 02139, (617) 253-7700.

Statistics Center

The Statistics Center, in conjunction with cooperating departments and Schools, helps to coordinate undergraduate programs in statistics and offers interdepartmental M.S. and Ph.D. degrees in statistics. It also provides a focal point for research, teaching, and consulting activities in statistics at MIT.

In order to concentrate (or minor) in statistics as an undergraduate, it is necessary to work out a program that will also fulfill the requirements of a department at MIT. This is most easily done in a department that has several faculty members teaching statistics subjects, e.g., Civil Engineering, Economics, Mathematics, and the Sloan School of Management.

A typical undergraduate program should include probability (e.g., 18.440 or 6.041), statistics (e.g., 15.075, 18.441, or 1.15), linear algebra (18.06), and at least three additional statistics courses, such as stochastic processes (6.262, 18.445), time series analysis (18.446), modeling and data analysis (15.078), sampling (18.454), experimental design (18.455), econometrics (14.388), and decision analysis (15.065).

Since much of modern statistics and data analysis involves computation, computer science subjects are also very useful. A coherent group of three subjects in an area of application (usually in the student's undergraduate department) is also important. For those interested in the theoretical aspects of statistics, these subjects could be partially replaced by subjects in mathematics and/or computer science.

For further information, contact the Statistics Center or Professor Roy Welsch (Sloan School), Professor Daniel McFadden (Economics), Professor Richard Dudley (Mathematics), or Professor Yosef Sheffi (Civil Engineering).

Students considering MIT for graduate study in statistics should seek the advice of the Statistics Center about which department or School would be most appropriate for admission to MIT. Once admitted to a department (or School), students pursue S.M., and Ph.D. programs in statistics in the department or under the general guidance of an interdepartmental committee established through the Dean of the Graduate School. The Statistics Center can also provide assistance in obtaining financial support.

The Statistics Center encourages graduate students already at MIT to obtain a minor in statistics or an M.S. in statistics while studying for other graduate degrees, especially the Ph.D.

Usually, S.M. degree programs can be completed in one year by students with backgrounds in linear algebra, probability, and statistics. A thesis is required for the S.M. degree and almost all theses in recent years have made contributions to applied projects. The doctoral programs for students in statistics can be individually planned in collaboration with various MIT departments.

Major theoretical fields of interest at the Statistics Center are recursive estimation, robust regression, categorical data analysis, statistical computing and graphics, detection of influential data, time-series analysis, choice models, econometrics, survival analysis, decision analysis, and probability theory.

Fields of application have ranged from microbiology and astrophysics to economics, and from the health sciences to the Massachusetts Lottery. Departments in which Center members are involved include Civil Engineering; Earth, Atmospheric, and Planetary Sciences; Economics; Electrical Engineering and Computer Science; Mathematics; and the Sloan School of Management.

The statistical consulting service at the Center gives students and faculty the opportunity to collaborate with researchers at MIT and neighboring institutions on projects covering the full range of statistical theory and practice on real problems.

While much of theoretical statistics draws heavily on mathematics, applied statistics is increasingly linked to computer science via numerical analysis, graphics, concurrent computing, and the development of expert systems for data analysis. These topics are a part of the rapidly growing field of computational statistics, which often forms a basic part of the Statistics Center's interdepartmental programs.

Further information, including a list of the statistics subjects offered at MIT, may be obtained by contacting one of the Codirectors, Professors Daniel McFadden, or Roy Welsch, Room E40-111, MIT, Cambridge, Massachusetts 02139, (617) 253-8722.

Technology and Development Program

The primary objective of the Technology and Development Program (TDP) is to provide a focus at MIT for interdisciplinary research and education related to the role of science and technology in the socioeconomic growth of developing countries. More specifically, the goals of the TDP are to promote an awareness among MIT faculty and students of the relationships among science, technology, and development; to provide a focal point for the activities of faculty, students, and visiting scholars interested in the field of technology and development; and to serve as a resource for organizations outside MIT (government, academic, private sector) that wish to explore the Institute's understanding of developing countries — particularly their socioeconomic and technological problems.

The TDP is administered by a policy committee with faculty from the Schools of Engineering, Humanities and Social Science, and Management.

The MIT/Cairo University Technological Planning Program was initiated in 1976, under TDP auspices, to assist Cairo University in the establishment of a Development Research and Technological Planning Center. Modeled on similar centers at MIT, this organization now provides an institutional mechanism at Cairo University for faculty members to conduct contract research with Egyptian and international organizations on development topics. Recently, the TDP has begun research on a regional and country basis in Latin America, the Middle East, Africa, and Asia.

TDP provides educational and research opportunities for master's candidates interested in specific areas of technology and development. Admission to MIT must first be obtained from the appropriate academic department. The student should then submit a proposal for study to the TDP policy committee for approval. Details of the program are available upon request. Students may receive financial support in the form of research assistantships associated with current TDP research projects.

Further information about the program, including a list of current research projects, may be obtained from the Office of the Director, Professor Fred Moavenzadeh, Room 1-173, MIT Cambridge, Massachusetts, 02139, (617) 253-7178.

Technology and Policy (S.M.)

The Technology and Policy Program prepares young men and women for competent leadership in the constructive development of technology. It educates "engineers and scientists with a difference," persons with both strong technical foundations and skills in dealing with important social concerns. It is unique in the opportunities it provides to combine a base in technology with skills in identifying, analyzing, and implementing solutions to policy issues.

Students in the Program work on problems in the wide range of technological fields available at MIT, for example computers, electronic systems, and communications; energy production and management; industrial innovation and productivity; disarmament; regulation of chemicals and pollution; transportation; marine and mineral resources; office automation; space technology; and solar and nuclear energy. A list of theses completed in the Program is available on request.

The Master of Science in Technology and Policy leads directly into practice, or continued study at MIT or elsewhere. Challenging jobs in industry, consulting, and government, both in the US and abroad, are open to our graduates. Many graduates of the program proceed to doctoral studies, either through departmental or interdepartmental arrangements. Others obtain further technical degrees or go on to law or business schools.

The curriculum is based on three subjects in each of four areas: 1) advanced competence in a specific technological area of the student's choice; 2) methods of policy analysis such as Engineering Systems Analysis (an Engineering School-Wide Elective subject) and 15.011 Applied Microeconomics; 3) the legal and political context of policy development, and specifically 17.202 or 17.220J, The Policy-Making Process; and 4) a core of integrative subjects. Academic credit is routinely granted for comparable studies done elsewhere.

Students determine individual curricula in consultation with their faculty advisors. We expect them to take full advantage of all the subjects available at MIT and, through cross registration, at Harvard. All students take two core subject, TPP 11J, and TPP 12J Proseminar in Technology and Policy. The proseminar helps students confront policy issues as they really are -- complex, difficult, often ill-defined, and full of conflicting values. It is the element that distinguishes this Program from just a set of subjects, and it provides the common ground where students meet to discuss issues of technology and policy.

A thesis is required. This is a major analysis in the student's field of interest. Students prepare for this effort by taking TPP 13J Master's Seminar. Theses frequently are published as reports or professional papers. Many graduates regard the thesis as the most significant part of their education at MIT.

Because clear expression is a practical necessity, students must demonstrate sufficient writing skills before beginning their thesis. New students take a diagnostic written exam in September. A seminar or course in technical writing may be required, depending on the results.

Students with prior interest and capabilities in technology and policy can complete the degree program in one calendar year. Others may need an additional semester.

Students typically obtain part-time jobs to support their education. These are mostly research assistantships on MIT projects that match their areas of specialization, for example, in the Center for Technology, Policy, and Industrial Development and the Energy Laboratory. A number of students will also find it desirable to work in off-campus internships. Teaching assistantships are also available.

Student funding is available through a number of grants and gifts to the Program. A Xerox Fellowship is awarded annually to a student interested in communications studies, Bernard Rabinowitz Fellowships are awarded for leadership in technology, a Champion International Thesis Fellowship is available for work on environmental issues, and several Jessie B. Noyes Foundation grants support students in water management studies. Several other partial tuition fellowships are available and are awarded on the basis of excellence and need.

The Program also offers two prizes: Best Thesis Award and the Alumni Award for Excellence and Leadership, which carries a tuition stipend.

Applicants should have a strong basis in engineering or science. Applications are reviewed by the Program and the MIT department corresponding to their particular interests. This process starts February 15 and candidates are notified as soon as possible.

The Program enrolls about 25 students each year. The class is limited to maintain close, collegial relationships between faculty and students, and to provide the best possible integration of Technology and Policy.

The steering committee for the Program consists of faculty members and student representatives from the Departments of Aeronautics and Astronautics, Chemical Engineering, Civil Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, Ocean Engineering, Political Science, and Urban Studies and Planning, as well as from the Center for Technology, Policy, and Industrial Development, the Energy Laboratory, and the Program in Science, Technology, and Society.

Further information may be obtained by contacting the Chair, Professor Richard de Neufville, Room 1-138, MIT, Cambridge, Massachusetts 02139, (617) 253-7693; the Associate Chair, Professor Joel Clark, Room 8-413, (617) 253-6885; or the Director of the Center for Technology, Policy, and Industrial Development, Professor Daniel Roos, Room E40-202, (617) 253-5322.

Undergraduate Research Opportunities Program (UROP)

The Undergraduate Research Opportunities Program (UROP) provides undergraduates the opportunity to participate with MIT faculty and research staff in a wide range of research activities throughout the Institute. Students may participate in ongoing research or find a faculty sponsor for a self-originated project. Work may be done for credit, pay, or on a voluntary basis. The same academic standards apply to all three modes.

The first several pages of the *UROP Directory*, published each year, give details on how to get started. Students are urged to read this before they embark on their research. Information on some current projects is posted on UROP bulletin boards in the main corridor of the Institute, and in the UROP section of the Undergraduate Education Office, Room 20B-141. New listings are announced each week in *Tech Talk*. Further information may be obtained by contacting the staff at the UROP Office, Room 20B-141, or by calling (617) 253-7909.

Students interested in research also may contact various laboratories and centers directly. For information about the opportunities for interdisciplinary research, see the description of the various interdepartmental laboratories, centers, and programs in the *UROP Directory* and in this chapter of the catalogue.

Undergraduate Seminars

The Undergraduate Seminar Program offers an opportunity for students to interact with faculty members in small, informal class settings. Seminars vary tremendously both in style and topic; some are oriented around small, informal class discussions while others bring in speakers, go out on field trips, or involve extensive laboratory projects. Some seminar instructors also serve as a freshman advisor to students in their class. Many of the topics are interdisciplinary, and taught jointly by members of several departments. Other seminar topics are of particular interest to faculty members but are outside of their department's usual scope.

For more details about the program, including titles and descriptions of seminars, see the *Undergraduate Seminar Program* booklet, issued twice yearly, and the *Freshman Advisor Seminars* issue of the MIT Bulletin, mailed in the summer to entering first-year students. These publications are available from the Undergraduate Academic Support Office, Room 7-104, MIT, Cambridge, Massachusetts 02139, (617) 253-3561.

Unspecified Degree Programs for Interdisciplinary Study (S.B.)

In a number of departments it is possible to pursue a less specialized "major," leading to an **undergraduate** degree that does not specify a professional field. To enroll for such a degree without specification, the student registers in the normal way in the department chosen. The flexibility of an unspecified degree program, coupled with appropriate advice from the home department and from other departments, can give students a valuable opportunity for interdepartmental study.

Wallace Geophysical Observatory

The George R. Wallace, Jr., Geophysical Observatory is a unique research facility designed to monitor ground motions and to aid in the development and testing of new seismic and other geophysical instrumentation. It is also a key component of MIT's nine-station seismic network in New England.

The Observatory, located 35 miles north of Boston in Westford, Massachusetts, has a large, multi-room underground vault and a surface control room. The vault has a controlled temperature environment and instrument piers resting directly on the basement granite. The Observatory contains sensitive seismometers and instruments for monitoring ground tilts and the earth's tidal motions. The Observatory also serves as a key station of the GEOSCOPE global seismic network. The surface building houses a work area and control and recording instruments. Data from the Observatory are telemetered directly to the Earth Resources Laboratory of the Department of Earth, Atmospheric, and Planetary Sciences. The data from the Observatory and the New England seismic network are recorded, analyzed, and displayed by a dedicated HP-1000 computer system, which is supplemented by a DEC MicroVAX computer. Data from the Observatory along with the numerous resources of the Department provide a unique facility for **undergraduates, graduate** students, and staff to pursue research concerning the interior of the earth.

Further information may be obtained by contacting the Director, Professor M. Nafi Toksoz, Room E34-440, MIT, Cambridge, Massachusetts 02139, (617) 253-7852.

Whitehead Institute for Biomedical Research

The Whitehead Institute for Biomedical Research provides educational and research opportunities for graduate and undergraduate students in the biological sciences.

At the Institute, developmental biology is studied using the modern tools of molecular biology. The goal is to understand the processes by which the fertilized egg develops into a mature organism.

Three major themes stand out in the investigative strategies of scientists at the Whitehead institute. In approaches that focus primarily on gene structure, scientists examine the most important individual genes in a particular developmental system. A second approach to understanding development at the molecular level employs defective developmental systems. Researchers try to identify and analyze the altered genes that cause the developmental defect. A third approach, that of cell biology, looks at the interplay of the molecules produced by individual genes.

The Institute is an independent, free-standing research facility adjacent to the MIT campus in Cambridge Center. It is affiliated with MIT through its faculty, who are also members in the MIT Department of Biology. Four other independent investigators hold positions as Whitehead Institute Fellows. Approximately 175 scientists are on the Institute staff.

Each year, a number of **graduate** students pursue Ph.D. degrees at the Whitehead Institute through the MIT Department of Biology. **Undergraduate** students pursue research objectives through the MIT Undergraduate Research Opportunities Program (UROP).

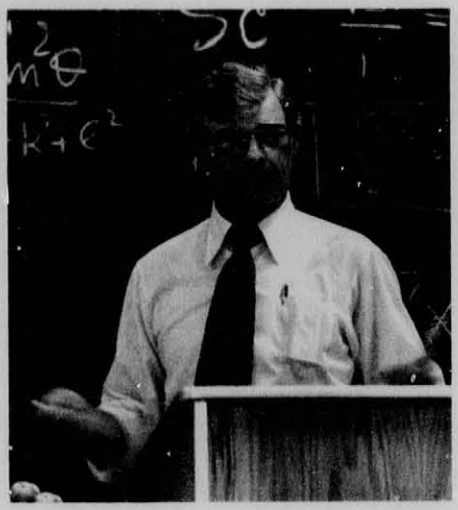
Further information may be obtained through the Office of the Director, Professor David Baltimore, Whitehead Institute, 9 Cambridge Center, Cambridge, Massachusetts 02142, (617) 258-5183.

Women's Studies Program

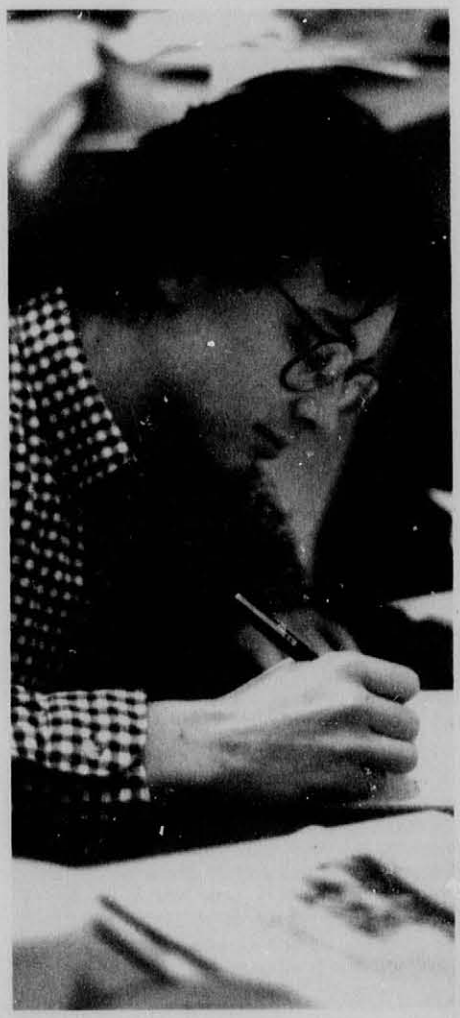
The Women's Studies Program offers unique opportunities for interdisciplinary study and research for both **undergraduate** and **graduate** students. The primary objective of Women's Studies is to encourage the reexamination and reinterpretation of existing data, as well as to promote new research about women and gender, in all disciplines, offering new perspectives in fields as diverse as anthropology, history, biology, psychology, engineering, and literature. Students can take a Humanities concentration, minor, or major (by petition) in Women's Studies. The curriculum includes two core subjects — Introduction to Women's Studies and Contemporary Issues in Women's Studies — and a selection of subjects from many departments at the Institute. Special independent study topics and UROP projects can be arranged. To facilitate interdepartmental research, the Women's Studies Research Room in the Humanities Library offers the MIT community a multidisciplinary resource for the study of women and gender. The Program is described in greater detail in Chapter III of this catalogue.


SOLON

VII Departmental Degree Programs and Requirements





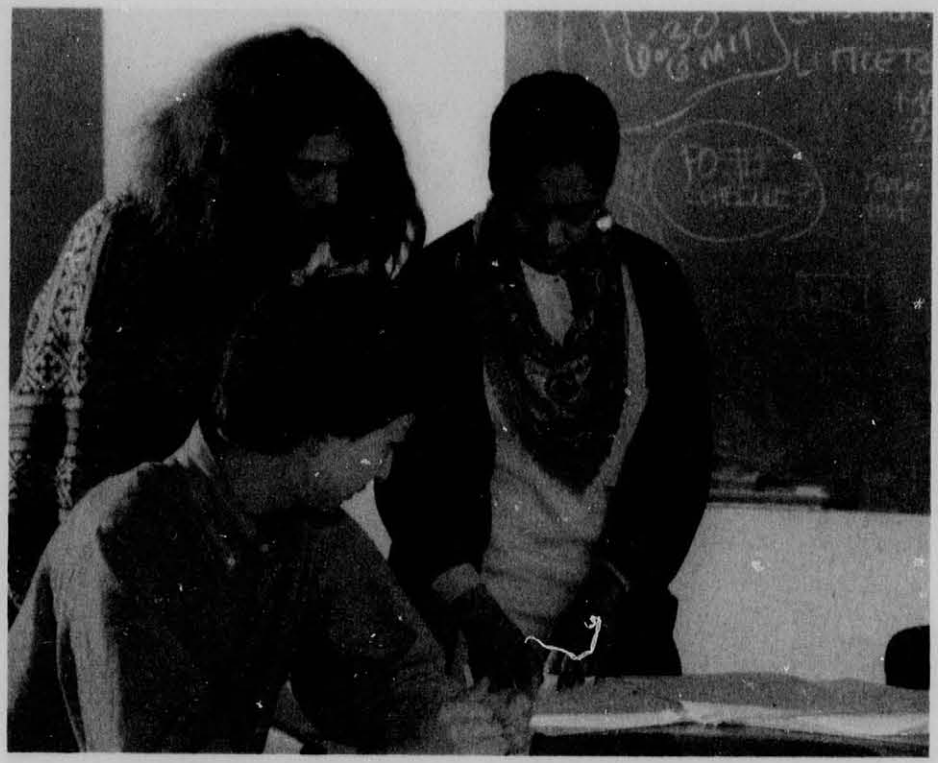






School of Architecture and Planning

Architecture (Course 4)
Urban Studies and Planning (Course 11)





The first university program in architecture in the United States began at MIT in 1865, and the second program in planning started in the 1930s. The present School of Architecture and Planning continues in the forefront of architecture and planning education, benefiting from the special collaborations fostered in a university of science and technology.

Today the School prepares students for professional careers that respond to the social, aesthetic, and technical demands of a growing variety of clients. The School is particularly concerned with services for communities that traditionally have lacked access to professional help. These goals are nourished by a culturally diverse student body and faculty, recruited with a special emphasis on minorities and women.

Departments and Special Programs

The School is host to the Department of Architecture, the Department of Urban Studies and Planning, and the Media Arts and Sciences Section. These divisions offer undergraduate, graduate-professional, and doctoral programs in architecture, planning, and media arts and sciences, which prepare students for practice research, and further study.

Two special programs allow mid-career practitioners from minority communities, who work in urban and regional development in the US and in developing countries, to study and pursue independent research during one academic year. In addition, the general Institute support for cross-registration at Harvard University gives professional students the opportunity to enrich their education at the Graduate School of Design and the Kennedy School of Government, among other areas.

International engagements and their relation to educational and professional goals are an important factor in the reach and influence of the School. These include master's degree tracks for planners in developing areas and design for Islamic cultures, the Special Program in Urban and Regional Studies (SPURS), and the Aga Khan Program for Islamic Architecture.

As part of a great research institution, the search for new knowledge includes independent scholarly research, with its written products and the consulting work that individuals carry out. In addition, the School provides a base for research in two laboratories — the Laboratory for Architecture and Planning and the Media Laboratory — as well as in several programs and the Center for Real Estate Development. The School also profits from collaborations with other parts of MIT, especially

in such fields as operations research, transportation, and energy technology. As research assistants, students have the opportunity to gain field experience in the public and private sectors and to formulate ideas for new proposals.

Laboratory of Architecture and Planning

This Laboratory initiates and administers research within the School, providing seed funds that enable projects to expand their support and move on to new, sometimes independent, phases. Recent projects have represented the areas of energy conservation and appropriate technology, building economics, design research, environmental impact assessment, dispute resolution, solar design, special needs housing, neighborhood and community development, and management of public participation for large-scale urban design projects. Areas of international focus include housing for developing countries and architecture and planning in East Asia.

Center for Advanced Visual Studies

Founded in 1967, the Center hosts a fellowship program for students devoted to the exploration of new artistic forms. The Center's main areas of interest are environmental art and design; and the interaction of art, science, and technology.

Media Laboratory

In the late 1940s, MIT pioneered in relating experiments in science and engineering to the visual arts. In 1963, innovations in computer systems that manipulate spatial data were introduced at MIT; in 1972, the Department of Architecture introduced television-based computer graphics, which resulted in the merger of video with computers.

For a School concerned with the quality of the human environment, an extension of scope to include the media environment has been as reasonable as the extension years ago from the physical to the social environment. The product of that extension is the School-based, Institute-wide Media Laboratory in MIT's new Wiesner Building. The Laboratory draws together such once discrete disciplines as film, graphics, photography, music, and computer science in combinations made possible by new digital video technologies and by advanced computer applications capable of simultaneously manipulating sound, images, and data. Special emphasis is placed on the design of opportunities that enhance human/machine interaction.

Center for Real Estate Development

Much of what the School does is associated with real estate development. The Department of Architecture educates students who, through their skills in design, give form to real estate development. The Department of Urban Studies and Planning teaches students to plan for and manage the consequences of investment and disinvestment in the urban environment. The research of each Department tries to understand the processes that shape and influence new development.

Recognizing the need to better understand the development process, the School created the Center for Real Estate Development in 1983. The Center sponsors a full agenda of research on issues related to real estate development. It also serves as the base for the Master of Science in Real Estate Development, an interdepartmental degree program that educates students to assume positions of responsibility in both public and private sector development organizations.

Computer Resource Laboratory/Project Athena

A computer facility shared by the Departments of Architecture and of Urban Studies and Planning is the School's chief link with Project Athena. In addition, several dozen work stations throughout the School are connected to one another and to the rest of the Institute via the Athena network. School faculty and students are developing a computer-based design support system that will enable exploration of new multimedia approaches for computer-assisted teaching of design and planning.

Office of the Dean

John de Monchaux, M.Arch.
Professor of Architecture and Urban Planning
Dean

Lois A. Craig, B.A.
Associate Dean

Diane McLaughlin, M.B.A.
Assistant Dean for Administration

Deborah Cohen, M.A.
Assistant Dean for Resource Development

Michael Joroff, M.C.P.
Director, Laboratory of Architecture and Planning

James McKellar, M.Arch., M.C.P.
Director, Center for Real Estate Development

Nicholas Negroponte, M.Arch.
Director, Media Laboratory

Otto Piene, M.A.
Director, Center for Advanced Visual Studies

Media Arts and Sciences Section

At MIT, the term Media Arts and Sciences signifies the study, invention, and creative use of new information technologies in the service of human expression and communication. The field, which is rooted in the communication, computer, and human sciences, addresses the quality of the information environment. The Media Arts and Sciences Section, established in 1987, began as a program in the Department of Architecture. The Section offers undergraduate and graduate subjects (numbered 4.870 to 4.999) and graduate study leading to the master's and doctoral degrees. Its academic programs are intimately linked with research programs within the Media Laboratory, which is made up of 11 research groups: Electronic Publishing, Learning and Epistemology, Speech Research, Music and Cognition, Advanced Television, Spatial Imaging, Graphics and Design, Vision Science, Film/Video, Computer Graphics and Animation, and Human-Machine Interface.

Master of Science

Students in the Master's program are required to complete their studies in a common culture that includes advanced placement or an MIT experience with computer programming, image and signal processing, spatial imaging, vision science, and studies of epistemology. The degree is awarded upon the satisfactory completion of an acceptable research thesis. The program requires four semesters of residence, of which one may be a summer term.

Doctor of Philosophy

Progress toward the Ph.D. degree follows a program of advanced study, including a proseminar, which is intended as preparation for a general examination in a major and two supporting fields, and a program of faculty-supervised research, which students begin in their first year. These lead, in turn, to the development of a program of original and significant research within one of the research groups, and to the completion and oral defense of a dissertation on that research.

Research Assistantships

The Media Laboratory strives to offer financial assistance to all successful applicants in the form of research assistantships, which are themselves an important part of graduate education. Assistantships require participation in research programs within the Media Laboratory; assistants normally register for two subjects and receive academic credit for part of their research.

Inquiries

Additional information concerning graduate academic and research programs, admissions, and assistantships may be obtained from Linda Peterson, Room E15- 218, MIT, Cambridge, Massachusetts 02139, (617) 253-5114.

Faculty and Staff in the Media Arts and Sciences Section

Stephen Anthony Benton, Ph.D.
Professor of Media Technology
Section Head

Professors

Muriel Ruth Cooper, B.F.A.
Professor of Visual Studies

Richard Leacock, D.F.A.
Professor of Cinema

Marvin Lee Minsky, Ph.D.
Donner Professor of Science in the Department of Electrical Engineering and Computer Science

Nicholas Peter Negroponte, M.Arch.
Wiesner Professor of Media Technology
Director, Media Laboratory

Seymour Aubrey Papert, Ph.D.
Professor of Education and Media Technology

William Francis Schreiber, Ph.D.
Professor of Electrical Engineering

Barry Lloyd Vercoe, D.M.A.
Professor of Media Arts and Sciences
Music Section, Department of Humanities

Associate Professors

Edward Howard Adelson, Ph.D.
Associate Professor of Visual Sciences

Alexander Paul Pentland, Ph.D.
Associate Professor of Computers, Communication, and Design Technology

Assistant Professors

Edith Karin Elsbeth Ackermann, Psych.D.
Assistant Professor of Media Technology
Fukutake Career Development Professor of Research in Education

Tod Machover, M.M.
Assistant Professor of Music and Media

Van Jay Wedeen, Ph.D.
Assistant Professor of Biological and Medical Imaging
Whitaker College

David Louis Zeltzer, Ph.D.
Assistant Professor of Computer Graphics
NEC Career Development Professor of Computers and Communications

Visiting Professors

Patrick A. Purcell, M.Des.
Associate Professor of Computer Graphics

Marilyn C. Schaffer, Ph.D.
Associate Professor of Early Childhood Education

Adjunct Professor

Arun N. Netravali, B.Tech., M.S., Ph.D.
Adjunct Professor of Media Technology

Lecturers

Glorianna Davenport, M.A.
Diana Gagnon, Ed.D.
Andrew Benjamin Lippman, S.M.

Technical Instructors

Victoria I. Bippart
Stuart R. Cody
William Francis Kelley
Adina Sabghir
Gregory L. Tucker
Julie Lynn Walker

Administrative Staff

Linda Gay Peterson

Postdoctoral Associate

David J. Heeger, Ph.D.

Professor Emeritus

Jerome Bert Wiesner, Ph.D.
Institute Professor, Emeritus
President, Emeritus

Department of Architecture

William Lyman Porter, M.Arch, Ph.D.
Professor of Architecture and Planning
Head of the Department

Leon Bennett Groisser, Sc.D.
Professor of Structures
Executive Officer

Professors

Stanford Anderson, M.Arch., Ph.D.
Professor of History and Architecture

Julian Beinart, M.C.P., M.Arch.
Professor of Architecture

John de Monchaux, M.Arch.
Professor of Architecture and Planning
Dean, School of Architecture and Planning

Leon R. Glicksman, Ph.D.
Professor of Building Technology

N. John Habraken, B.I.
Professor of Architecture
(On leave, fall)

Imre Halasz, Dipl. Arch.
Professor of Architecture

Tunney F. Lee, B. Arch.
Professor of Architecture and Urban Studies and Planning
Head, Department of Urban Studies and Planning

Ronald Bentley Lewcock, B.Arch., Ph.D.
Aga Khan Professor of Design for Islamic Cultures
Chairman, Aga Khan Program for Islamic Architecture

John Randolph Myer, B.Arch.
Professor of Architecture
(On leave, fall)

Otto Piene, M.A.
Professor of Visual Design
Director, Center for Advanced Visual Studies

Maurice Keith Smith, B.Arch.
Professor of Architecture

Associate Professors

Ranko Bon, Ph.D.
Associate Professor of Building Economics and Technology
George Macomber Career Development Professor in Construction Management

Eric Dluhosch, M.Arch., Ph.D.
Associate Professor of Building Technology

David Hodes Friedman, Ph.D.
Associate Professor of the History of Architecture
(On leave)

Sandra C. Howell, Ph.D.
Associate Professor of Behavioral Science in Architecture

Jan Wampler, M.Arch.
Associate Professor of Architecture

Assistant Professors

Rosemary Grimshaw, M.Arch.
Assistant Professor of Architecture

William Hubbard, B.Arch., S.M.Arch.S.
Assistant Professor of Architecture

Leila W. Kinney, M.A.
Assistant Professor of the History of Art

Frank Miller, M.Arch.
Assistant Professor of Computer-Aided Architectural Design

Leslie Keith Norford, Ph.D.
Assistant Professor of Building Technology

Francesco Passanti, Ph.D.
Assistant Professor of the History of Architecture
(On leave, fall)

Visiting Professors

Henry A. Millon, B.Arch., M.Arch., Ph.D.
Professor of History and Architecture
(Fall)

Erich Schneider-Wessling, Dipl.Ing.
Professor of Architecture
(Fall)

Maristella Casciato, Laurea
Assistant Professor of the History of Architecture
(Fall)

Edward Kaufman, Ph.D.
Assistant Professor of the History of Architecture
(Fall)

Andrew Morrogh, Ph.D.
Assistant Professor of the History of Architecture

Adjunct Professor

Richard Chester Tremaglio, M.Arch.
Adjunct Professor of Architecture

Principal Research Associates

Reinhard Goethert, M.Arch., Ph.D.
Timothy E. Johnson, S.M.

Research Associate

Edward Robbins, Ph.D.

Lecturers

Nishan Bichajian
Michael Buckley, M.A.A.S.
Thomas Chastain, M.Arch.
Renee Chow, M.Arch.
George Clark, B.S.
John Crowley, M.Arch.
Fernando Domeyko, Dipl. Arch.
Fred Dubin, B.S., M.Arch.
John Furlong, M.L.A.
Dennis Frenchman, M.Arch., M.C.P.
Nabeel Hamdi, Dipl. Arch.
Shun Kanda, M.Arch.
Yim Lim, M.Arch.
Carl Rosenberg, M.Arch.
Peter Roth, M.Arch.
Barry Zevin, M.Arch.

Technical Instructor

Christopher Dewart, B.A.

Administrative Officer

Anne Shepley, B.A.

Assistant to the Head of the Department

Nancy Jones, B.A.

Administrative Assistant

Linda Okun, M.A.

Professors Emeriti

Wayne V. Andersen, Ph.D.
Professor of the History of Art, Emeritus

Lawrence Bernhart Anderson, M.Arch.
Professor of Architecture, Emeritus
Dean of the School of Architecture and Planning, Emeritus

Herbert Lynes Beckwith, M.Arch.
Professor of Architecture, Emeritus

Pietro Belluschi, Dott. Ing., LL.D., Sc.D., D.F.A.
Professor of Architecture, Emeritus
Dean of the School of Architecture and Planning, Emeritus

Horacio Caminos, Arq.
Professor of Architecture, Emeritus

Eduardo Fernando Catalano, M.Arch.
Professor of Architecture, Emeritus

Albert George Henry Dietz, Sc.D.
Professor of Building Engineering, Emeritus

Richard Filipowski, B.A.
Associate Professor of Visual Design, Emeritus

Gyorgy Kepes, M.A.
Institute Professor, Emeritus
Professor of Visual Design, Emeritus
Director, Center for Advanced Visual Studies, Emeritus

Robert Ormerod Preusser
Professor of Visual Design, Emeritus

Chester Lee Sprague, M.Arch.
Associate Professor of Architecture, Emeritus

Waclaw Piotr Zalewski, D.Tech.Sci.
Professor of Structures, Emeritus

Department of Architecture

(Course 4)

Undergraduate Study

The Department of Architecture includes a number of diverse fields of interest in architecture and the arts. The programs encourage students to combine theoretical interest with tangible application and to consider the social consequences of their work. The diversity of attitudes and working methods in the Department make possible a variety of alternative career paths. Undergraduate and graduate students have the opportunity to structure their own academic programs to suit their special aptitudes and interests within an overall curriculum framework.

The Department offers five degree programs: the Bachelor of Science in Art and Design, the Master of Architecture, the Master of Science in Architecture Studies, the Master of Science in Visual Studies, and the Doctor of Philosophy. The Department is composed of five discipline groups: architectural design; architecture studies; building technology; history, theory, and criticism of architecture and art; and arts and media technology. Students in each degree program are encouraged to take subjects in the different discipline groups.

Architectural design is taught from a broad range of perspectives linking several common concerns: site and context, use and form, building methods and materials, and the role of the architect. Context is considered in terms of existing and historical physical form (natural and constructed) and sociological patterns of use. The role of the architect is less often seen as the sole creator of a completed building than as a participant with user groups, or as a generator of a structure to which users may add or alter over time.

A broad range of architectural design studios is offered. Rather than a single core curriculum, the focus is on a set of design projects of ascending complexity. Introductory studios provide a basic architectural design background and vocabulary and help undergraduates decide whether they want to continue in architecture. The design method studios provide a range of experiences of form-making in which individual faculty present their particular ways of exploring a design issue. The advanced studios give graduate students the opportunity to sharpen their skills and to develop their own attitudes of form-making. In their theses, students carry through a project of their own from concept through theory and design to a final product.

The School's new computer center is available to experiment with modeling techniques, graphic representations, design methods, and assistance with the design process itself. In addition, students may participate in research work in these areas.

The emphasis in **Architecture studies** is on combining the study and practice of shaping the built environment with research on the built environment, on the forces that mold it, and on the design process itself, and covers such areas as large-scale physical settings, behavioral studies, environmental programming, the form and evaluation of cities, design theory and methodology, decision-making procedures in design, housing and settlement forms in developing countries, and self-help processes. Central to these topics is the role of the user as an active force in the development of environments and the role of the designer as an agent in the process of human habitation.

Building technology includes teaching and applications of the fundamentals of technology as well as research in technology for the next generation of buildings. Topics include building structures, materials, industrialized building systems, energy in buildings, solar architecture, and economics. Subjects include fundamentals of technology, applications to buildings, design studios, laboratories, and independent research projects. Students may, for example, study problems of energy resources and technologies and use this to design physical environments or buildings for the next decade embodying concepts currently in research. Research facilities include the Energy Efficient Buildings and Systems Program, the Lighting Laboratory, and the MIT Solar Building No. 5. Research facilities of other departments such as Mechanical and Civil Engineering are also used in joint research projects.

The **History, theory, and criticism of architecture and art** group emphasizes ways of developing and organizing concepts as well as understanding the physical and social context of an architect's and artist's works. The group is most concerned with the creative process itself, both in understanding the meanings of architects' and artists' actions and, more importantly, in being able to contribute directly to analytical and design processes (including work in architectural design studios).

The history of architecture offerings deal with social and physical contexts of the built environment on many scales. While not limited to any particular period of time, they generally focus on contemporary understanding relevant to the basic premises on which architects work. Theory and criticism of architecture serve as the methodological bases for evaluation of the premises, the process, the final product, and the implications (social, formal, and other) of proposed action and nonaction. They study the development of and changes in significant attitudes about architectural works.

The Department offers two undergraduate courses of study: Course IV, leading to the Bachelor of Science in Art and Design, and Course IV-B, leading to the Bachelor of Science.

Bachelor of Science in Art and Design Course IV

Course IV offers a flexible program for students in four possible areas of concentration: visual arts (including visual design, photography and spatial imaging, the Visible Language Workshop, and filmmaking); architectural design; building technology (including structures, building process, energy systems, and environmental control); and history, theory, and criticism of architecture. Within a broad framework, students develop individual courses of study best suited to their needs and interests.

The requirements for the S.B. in Art and Design curriculum begin with an introductory subject, 4.01 Issues in Architecture, designed to be taken by freshmen and sophomores. The remaining Restricted Electives include beginning work in the arts, architecture and the building process, and the history and social context of art and architecture.

Undergraduates interested in technology and architecture should consult a faculty advisor in Building Technology. They can plan a course concentration including structures, thermal systems, building systems, computer-aided design, and economics. A joint program with a department in Engineering can also be structured.

Students should discuss their educational interests and plans with a faculty advisor not later than the beginning of the fall term of their junior year. The Department has prepared charts which give the subject requirements for each of its four areas of concentration. Each area of concentration provides a variety of subjects among which to choose, as well as an opportunity to get deeply involved in a particular subfield.

Students who plan to continue their studies for the graduate degree, Master of Architecture, must apply for admission to the graduate M.Arch. program. Students who have fulfilled the requirements for the Bachelor of Science in Art and Design normally are able to satisfy the requirements for the M.Arch. in two years if they include in their undergraduate program a sufficient number of professional subjects. This requires careful use of a student's Unrestricted Electives.

Students who intend to continue with graduate studies in the visual arts, building technology, and history, theory, and criticism of architecture should consult with an appropriate faculty member to design a program of study which establishes the basis for graduate study.

Bachelor of Science in Art and Design Course IV

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:†

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by subjects in the Departmental Program]*	8
Science Distribution Requirement [can be satisfied by 4.30, plus appropriate subjects]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Restricted Electives:	**66-69**
One subject from each of the following six groups:	
Group 1 Introductory Subject	
4.01 Issues in Architecture, 12	
Group 2 Design Information	
4.870 Words, Images, Graphics Tools, and Ideas, 12	
4.26 Observing Form in Context, 12; 4.01	
Group 3 Environmental Technology	
4.911 3-D Computer Graphics, 12	
4.402J Building Construction I, 12	
Group 4 History of Art and Architecture	
4.605 Introduction to the History and Theory of Architecture, 9	
4.642 19th-Century Art, 9	
4.645 Selected Topics in Architecture — 1750 to the Present, 9; 4.605	
4.651 20th-Century Art, 9	
Group 5 Social Context	
11.001 Introduction to Urban Design and Development, 12	
11.002 Introduction to Public Policy Analysis and Government Action, 12	
11.131 The Urban Neighborhood, 12	
Group 6 Arts	
4.823 Form and Design I, 12	
4.825 Form and Color, 9	
4.891 Creative Photography I, 12	
Planned Electives	**up to 75**
A coherent set of six subjects within one of the following areas of concentration (in addition to a restricted elective in the area): Architectural Design; Building Technology; History, Theory, and Criticism of Architecture; Visual Arts. (A 21- or 24-unit design subject would count as two subjects.) See Department for details.	
Units in Departmental Program that also satisfy the General Institute Requirements	**(9-12)**
Unrestricted Electives	**at least 48**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

†The degree requirements applicable to classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

*Only one subject in the fields of Visual Arts and Design, History of Art and Architecture, and Urban Studies used in fulfillment of the Departmental Program may be used to satisfy the Humanities, Arts, and Social Sciences (HASS) Requirement. Students cannot have the same departmental area of concentration and HASS Field of Concentration.

Bachelor of Science Course IV-B

Course IV-B is offered for students who find that their basic intellectual commitments are to subjects within the Department of Architecture but whose educational objectives cut across departmental boundaries. These students may, with the approval of the Department, plan a course of study that meets their individual needs and interests while including the fundamental areas within the Department. For example, students might create a coherent program combining subjects in architecture with subjects in urban studies and planning, computer sciences, systems analysis, acoustics, etc.

As early as possible, students should discuss their interests and intended programs with Department faculty members. Students desiring to follow this curriculum must submit to the Department, not later than the beginning of the fall term of their junior year, a statement of educational goals, including a list of the restricted, planned, and unrestricted electives selected to achieve these goals.

The Course IV-B curriculum is similar to Course IV, except that students need take only one subject each from five of the six groups shown in the Course IV curriculum, plus a coherent program of planned electives (96 units) leading to a well-defined interdisciplinary goal. Further details may be obtained from the Department.

Students in either program of the Department of Architecture may, upon consultation with a faculty advisor, exercise flexibility in scheduling completion of the General Institute Requirements. It should be emphasized, however, that any program of studies that involves postponing first-year physics and mathematics limits the possibilities of transferring easily to (or taking advanced subjects in) those departments that presuppose the completion of most of the General Institute Science Requirements by the end of the sophomore year.

1
Subjects in the fields of Visual Arts and Design, History of Art and Architecture, and Urban Studies used in fulfillment of the Departmental Program may **not** be used to satisfy the Humanities, Arts, and Social Sciences (HASS) Requirement. Students cannot have the same departmental area of concentration and HASS Field of Concentration.

2
The subject 4.30, if elected, can be used to satisfy part of the Science Distribution Requirement, thereby providing 12 additional units of Unrestricted Electives.

Graduate Study

Bachelor of Science in Art and Design
Course IV

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement[1]	72
Science Distribution Requirement[2]	36
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Restricted Electives: 66-69

One subject from each of the following six groups:

Group 1 Introductory Subject
4.01 Issues in Architecture, 12

Group 2 Design Information
4.911 3-D Computer Graphics, 12
4.26 Observing Form in Context, 12; 4.01

Group 3 Environmental Technology
4.30 Basic Structural Theory[2] 12; 8.02, 18.02
4.402J Building Construction I, 12

Group 4 History of Art and Architecture
4.605 Introduction to the History and Theory of Architecture, 9
4.642 19th-Century Art, 9
4.645 Selected Topics in Architecture — 1750 to the Present, 9; 4.605
4.646 American Landscapes, Towns, and Buildings, 9; 4.605
4.651 20th-Century Art, 9

Group 5 Social Context
11.001 Introduction to Urban Design and Development, 12
11.002 Introduction to Public Policy Analysis and Government Action, 12
11.131 The Urban Neighborhood, 12

Group 6 Arts
4.821 Visual Projects I, 9
4.823 Form and Design I, 12
4.825 Form and Color, 9
4.870 Words, Images, Graphics Tools, and Ideas, 12
4.891 Creative Photography I, 12
4.971 Introduction to Moviemaking, 12

Planned Electives: at least 69

A coherent set of subjects within one of the following areas of concentration (in addition to a restricted elective in the area): Architectural Design; Building Technology; History, Theory, and Criticism of Architecture; Visual Arts. See Department for details.

Unrestricted Electives[2] 45

Total Units Required for the S.B. Degree 360

The Department offers four graduate degree programs — the Master of Architecture, the Master of Science in Architecture Studies, the Master of Science in Visual Studies, and the Doctor of Philosophy.

The Master of Architecture is awarded to students who complete a program, accredited by the National Architectural Accrediting Board, that is an essential step toward licensure for architectural practice.

The Master of Science in Visual Studies program explores arts and media technology; it accepts only students who have already demonstrated a high level of competence and achievement in their field.

The Master of Science in Architecture Studies program stresses research and inquiry in the built environment; the degree is meant both for students who already have their first professional architecture degree and those whose previous education matches the program.

The Ph.D. program is an advanced degree program initiated in the area of History, Theory, and Criticism, but is being expanded to other areas — specifically Design Methodology, and Media Technology.

Master of Architecture

The Master of Architecture is awarded upon the satisfactory completion of an approved program of at least 164 units, of which 96 units must be in "A" subjects, and an acceptable thesis. Completion ordinarily requires at least two years of residence beyond the Institute's undergraduate Bachelor of Science in Art and Design. A substantial number of candidates are admitted with a Bachelor's degree from other institutions. Those who have not yet studied in a department of architecture require at least three and one-half years of residence to fulfill the requirements for the M.Arch. degree.

The professional M.Arch. program is seen as being diverse and open-ended with many views of an appropriate theory and practice of architecture available, yet with a general set of shared concerns. These include a commitment to design, a concern for the behavior of people and their participation in creating architecture, an interest in inquiry and criticism, a view of the environment as a living and developing phenomenon, an interest in the relation between the built environment and institutions, a regard for the material processes of building, and a concern for the spatial and temporal contexts of buildings.

Architectural design studios are the center of the M.Arch. degree program. Students must recognize that there are many possible professional roles, and therefore must assume much of the responsibility for structuring their own educational programs. While the professional curriculum specifies that a student study a range of subjects in several interrelated fields, students in the M.Arch. program have a number of choices within each of the study areas offered in the Department, and have the opportunity to concentrate in one area which they may define.

Master of Science in Visual Studies

This program offers graduate education in visual studies and visual media with emphasis on their technological development, communications applications, and use in and as art. It is open to students from varied backgrounds.

The degree is awarded upon satisfactory completion of an approved program of study and submission of an acceptable thesis. The program requires four semesters of residency, one of which may be a summer term.

Master of Science in Architecture Studies

This program is designed to provide a climate for research and inquiry that stresses the investigative component of understanding the built environment. It is open to students with professional degrees in architecture, or to students with degrees in other fields who demonstrate experience and significant achievement in those fields. The S.M.Arch.S. degree is awarded upon satisfactory completion of an approved program of study and the completion of an acceptable thesis. The Department requires two full academic years of residency.

The program has a strong interest in the methods of inquiry, development and testing of knowledge, and the building and application of theory as it pertains to the built environment. It allows students to specialize in areas in which they wish to obtain particular abilities. The four major areas of study are:
1) Environmental Design — a joint enterprise of the Department of Architecture and the Department of Urban Studies and Planning. Major interests include environmental design, models and evaluation, policy analysis, behavior and programming, and history and theory.
2) Housing and Settlement Design — which concentrates on issues of human habitation as related to design, and deals with problems in developing countries. Subareas of research and teaching are methods, behavior studies, technology, and settlement design.
3) Building Technology — concentrating on the development of the next generation of

technology for buildings as well as the innovative application of state-of-the-art concepts to building systems. Research programs, in many cases jointly carried out with faculty and students in the School of Engineering, include advanced thermal insulation concepts, solar energy building envelope systems, composite materials, air circulation in building interiors, housing systems for developing countries, building management and economics, and real property management.
4) Design for Islamic Cultures — which concentrates on issues concerning regional and cultural identity in the design of buildings, and the relationship between urban design and architectural form in Islamic and other non-Western societies. Subareas of research are appropriate building technology, climate, conservation and preservation, and the development of new design vocabularies.

An additional area — History, Theory, and Criticism — admits only a few S.M.Arch.S. students each year. They work alongside doctoral students in the program, and, as a result, are able to carry their learning experience back to architectural practice or design education. The strength of the faculty in this area lies in the period from the late Middle Ages to the present.

About 70 percent of the students in the S.M.Arch.S. program come from outside the United States; this encourages the exchange of ideas across cultures. Students often use a site in their home countries as a base for their theses.

Doctor of Philosophy

The Ph.D. program in Architecture, Art, and Environmental Studies is primarily in the area of History, Theory, and Criticism. It draws upon the unique range of disciplines and professions within the Department of Architecture and emphasizes the study of Western (19th and 20th centuries) and Islamic architecture and urbanism, and methodological issues that inform or link historical and practical work. A small number of Ph.D. candidates may work in close association with the faculty and its research in two areas: studies in architecture and environmental structure; and studies in Islamic architecture and urbanism (part of the Aga Khan Program for Islamic Architecture). In addition, some students are working in the area of design methodology and building technology.

Candidates for the program should have a Master's degree or the equivalent. Previous university work may be in academic or professional schools, and in the history of architecture; some professional experience is recommended also. Candidates with degrees from other institutions are required to be in residence for two academic years.

Each student admitted to the program should consult with one principal professor to work out both a three-person advisory committee and a general plan of study. Progress through the program follows a sequence of subject work, qualifying papers, general examinations in major and minor fields, and dissertation writing and defense. Proficiency in two languages is mandatory. Students are encouraged to take subjects appropriate to their programs in other departments at MIT, and at Harvard and Wellesley; active collaboration with MIT's gallery and exhibitions program and with other institutions in the Boston-Cambridge area also is possible.

Inquiries

Further information concerning undergraduate and graduate academic programs in the Department, admissions, financial aid, and assistantships may be obtained from the Department of Architecture, Room 7-303, MIT, Cambridge, Massachusetts 02139, (617) 253-7791.

Department of Urban Studies and Planning

Tunney F. Lee, B.Arch.
Professor of Architecture and Urban Studies and Planning
Head of the Department

Professors

John de Monchaux, M.Arch.
Professor of Architecture and Planning
Dean, School of Architecture and Planning

Robert M. Fogelson, Ph.D.
Professor of History and Urban Studies

Bernard Joel Frieden, M.C.P., Ph.D.
Professor of City Planning
Chair of the Faculty

Ralph A. Gakenheimer, M.R.P., Ph.D.
Professor of Urban Studies and Planning and Civil Engineering

Gary Hack, M.Arch., M.U.P., Ph.D.
Professor of Urban Design

Bennett Harrison, Ph.D.
Professor of Political Economy and Planning
(On leave, spring)

Frank Sidney Jones, M.B.A.
Ford Professor of Urban Affairs
(On leave, fall)

Langley Carleton Keyes, Ph.D.
Professor of City and Regional Planning

Gary T. Marx, Ph.D.
Professor of Sociology

Karen R. Polenske, Ph.D.
Professor of Regional Political Economy and Planning

William Lyman Porter, M.Arch., Ph.D.
Professor of Architecture and Planning
Head, Department of Architecture

Martin Rein, M.S.W., Ph.D.
Professor of Sociology

Donald Allen Schon, Ph.D.
Ford Professor of Urban Studies and Education

Lawrence E. Susskind, M.C.P., Ph.D.
Professor of Urban Studies and Planning

Lance Taylor, Ph.D.
Professor of Nutritional Economics

Judith Tendler, Ph.D.
Professor of Political Economy
(On leave)

Associate Professors

Lawrence Bacow, J.D., Ph.D.
Associate Professor of Law and Environmental Policy

Phillip L. Clay, Ph.D.
Associate Professor of Urban Studies and Planning

Joseph Ferreira, Jr., S.M.E.E., Ph.D.
Associate Professor of Urban Studies and Operations Research

Lynne Bayer Sagalyn, M.C.P., Ph.D.
Associate Professor of Planning and Real Estate Development

Bishwapriya Sanyal, M.C.P., Ph.D.
Associate Professor of Urban Studies and Regional Planning
(On leave, spring)

J. Mark Davidson Schuster, Ph.D.
Associate Professor of Urban Studies and Planning

William Cody Wheaton, Ph.D.
Associate Professor of Economics and Urban Studies

Assistant Professors

Merrie G. Klapp, Ph.D.
Assistant Professor of Environmental Studies and Planning

Edwin Meléndez, Ph.D.
Assistant Professor of Urban Studies and Planning
(On leave)

Lyna L. Wiggins, Ph.D.
Assistant Professor of Urban Studies and Planning

Visiting Professors

James McKellar, M.Arch., M.C.P.
Professor of Architecture and Planning
Director, Center for Real Estate Development

Michael Wheeler, J.D., LL.M.
Professor of Law
Director of Education, Center for Real Estate Development

Ronald Ferguson, Ph.D.
Associate Professor of Public Policy

Karen Fulbright, Ph.D.
Assistant Professor of Urban Studies and Planning

Adjunct Professors

Philip Barnard Herr, M.C.P.
Adjunct Professor of City Planning

Melvin H. King, M.Ed.
Adjunct Professor of Urban Studies and Planning
Director, Community Fellows Program

Senior Lecturers

Michael Joroff, M.C.P.
Director, Laboratory of Architecture and Planning

Edward J. Logue, L.L.B.

Alan Strout, Ph.D.
Director, Special Program for Urban and Regional Studies (SPURS)

Lecturers

Alice Amsden, Ph.D.
(Visiting)

Shlomo Angel, Ph.D.
(Visiting)

David L. Birch, D.B.A., Ph.D.
Senior Research Scientist, Laboratory of Architecture and Planning

Louise Dunlap, Ph.D.

John Ehrenfeld, Sc.D.
Senior Research Associate

Dennis Frenchman, M.C.P., M.Arch.

Gillian Hart, Ph.D.
(Visiting)

Remy Prud-Homme, Ph.D.
(Visiting)

Arthur Row, M.C.P.
Director of SPURS Summer Program
(Visiting)

Thomas A. Stokes, M.C.P.

Administrative Officer

Rolf R. Engler, A.S.A.

Professors Emeriti

Roland Bradford Greeley, M.C.P.
Professor of Regional Planning, Emeritus

Aaron Fleisher, Sc.D.
Professor of Urban and Regional Studies, Emeritus

John Tasker Howard, M.C.P.
Professor of City Planning, Emeritus

Lisa Redfield Peattie, Ph.D.
Professor of Urban Anthropology, Emeritus

Lloyd Rodwin, M.P.A., Ph.D.
Senior Lecturer
Ford International Professor, Emeritus

Department of Urban Studies and Planning

(Course 11)

Undergraduate Study

The Department of Urban Studies and Planning (DUSP) offers several degree and nondegree programs: Bachelor of Science in Planning; Master of City Planning; Master of Science in Urban Studies and Planning; Doctorate in Urban Studies and Planning; joint programs with the Departments of Architecture, Civil Engineering, Political Science, and Economics; a Special Program in Urban and Regional Studies (for mid-career professionals from less developed areas); the Community Fellows Program (for mid-career professionals from communities of color in the United States); and special student status for part-time mid-career professionals interested in taking individual courses.

City and regional planners in the US and other parts of the world are involved in a variety of activities aimed at shaping the pattern of human settlements and providing housing, public services, employment opportunities, and other crucial support systems that comprise a decent living environment. Planning encompasses not only a concern for the structure and experience of the built environment, but also a desire to harness the social, economic, political, and technological forces that give meaning to the everyday lives of men and women in residential, work, and recreational settings. Planners operate at the neighborhood, metropolitan, state, or national level, in both the public and private sectors. Their tasks are the same: to help frame the issues and problems that receive attention, to formulate and implement programs and policies responsive to individual and group needs, and to work with and for various communities in allocating both economic and natural resources most efficiently and most equitably.

Planners are often described as "generalists-with-a-specialty." Specialties have been thought of in functional terms (such as housing, transportation, land use, health care) or in terms of the geographic levels at which decision making takes place (neighborhood planning, town planning, regional planning, planning for national development). Subspecialties within the planning field also have been described in terms of the roles that planners are called upon to play, such as manager, designer, regulator, advocate, evaluator, or futurist.

The Department of Urban Studies and Planning seeks to educate professionals and scholars who as practitioners are able to deal with the processes of urban and regional development, environmental planning and design, and public policy analysis and implementation. The Department is committed to educating planners who can advocate the interests of underrepresented constituencies.

A focus on practice and the development of practice-related skills is central to the Department, particularly to students in the professional degree (M.C.P.) program. One means of acquiring these practice-related skills and of integrating them with classroom knowledge is through the Department's fieldwork and internship programs. Through fieldwork, students can acquire competence by working with capable practitioners and then bringing field experiences back into the academic setting for reflection and discussion. Students may work in community organizations or government agencies, or under the direction of faculty members involved in field-based projects for outside clients. Academic credit is awarded according to the time committed. In some cases stipends are related to fieldwork or internship programs.

Specific opportunities for concentration and specialization available to students are included in the descriptions of the degree programs that follow.

During the month of January, the Department of Urban Studies and Planning offers a series of "mini-subjects" in specialized fields not covered by the regular curriculum — unique opportunities provided by the Institute-wide January Independent Activities Period. Some of these are student-organized activities that subsequently have been incorporated into the academic program.

Bachelor of Science in Planning Course XI — Option 1

The Department of Urban Studies and Planning offers an interdisciplinary preprofessional program designed to prepare students for careers as planners, analysts, advisors, and managers in either the public or private sectors. Course work stresses knowledge and skills for: 1) defining and responding to community needs, 2) evaluating and designing public policies and programs, and 3) allocating resources in an efficient and equitable manner.

The core of the program provides basic knowledge of community and environmental systems; the social science concepts used to describe them; and the methods and techniques with which they can be analyzed, planned, and changed. Students begin with one introductory subject linked to either the design or policy side of planning, plus three social science subjects introducing basic concepts from the disciplines of sociology, political science, and economics. The two-subject sequence in planning and applied social research then builds on these introductory subjects to develop skills in practical problem solving. Students are also expected to sharpen their analytic skills through both the required statistics subject and the laboratory.

Student participation in departmental research and public sector internships is an important part of the program. Faculty members will help students formulate, design, and undertake a personal project synthesizing what they have learned. The project may involve a focused attempt at analysis, or a report on a problem-solving experience accomplished either through a fieldwork assignment or as the result of a workshop.

Students are free to develop their own specializations in consultation with their advisors or may select one of the three areas suggested by the Department:

Environmental Planning serves students seeking careers in managing and analyzing the quality of the environment. Students may subsequently become specialists in planning, law, engineering, or other "environmental professions" such as landscape architecture, water resource management, and air pollution control. This specialization examines the form and function of natural and urban systems, techniques for describing and evaluating environmental change, approaches to analyzing and implementing environmental policy, and mechanisms for assessing the choices posed by the environmental impacts of technological advances.

Neighborhood and Community Planning emphasizes the study of the built environment; and techniques of describing, evaluating, and guiding spatial and physical change. Students learn about interactions between communities and the people who inhabit them. They acquire skills in defining needs and goals, in assessing alternative development patterns and policies, and methods for implementing planned changes in urban areas. The specialization relates economic and political aspects of development to planning methods and theory.

Public Policy, Urban Management, and the Law focuses on the nature of public institutions, the processes of policy formation, analysis, and implementation, and research and management techniques for planning and executing public policy. Subjects examine factors that influence public choices — political and economic interests, social structure, and value considerations. Fieldwork and internship subjects give students experience that helps develop skills in analysis and management. This specialization prepares students for subsequent work in government, public administration and management, and law.

Bachelor of Science in Planning Course XI — Option 1

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [all but three Humanities Distribution subjects can be satisfied by subjects in the Departmental Program]	8
Science Distribution Requirement[1]	3
Laboratory Requirement [can be satisfied by 11.188 or 17.203 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	**103-117**
Group I: Introduction	
One of the following two subjects:	
11.001 Introduction to Urban Design and Development, 12	
11.002 Introduction to Public Policy Analysis and Government Action, 12	
Group II: Social Science	
11.006J American Society: Values, Institutions, and Variety, 12	
11.007J Politics and Public Policy, 12	
14.01 Principles of Microeconomics, 9	
Group III: Planning and Applied Social Research	
11.003 Planning and Applied Social Research I, 12; 11.007J, 14.01	
17.203 Political Science Laboratory, 12	
11.188 Social Research Methods, 12	
6.041 Probabilistic Systems Analysis, 12	
Group IV: Senior Project	
Senior Project (10-24 units)	
Planned Electives: A coherent selection of five subjects in planning and applied social science developed in consultation with the student's departmental advisor. The student must include at least one additional social science subject, such as 11.008J Economic Structure of Cities or 11.014J American Urban History II; at least 12 units of approved internship, fieldwork, or workshop experience; and at least three subjects comprising an approved area of specialization (described in text).	**at least 48**
Units in Departmental Program that also satisfy the General Institute Requirements	**(57-66)**
Unrestricted Electives	**72-92**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

Bachelor of Science in Planning Course XI — Option 2

This option, in cooperation with Civil Engineering, is designed for students who want to combine the skills of the two fields. Such programs concentrate, for example, on environmental engineering, on transportation systems related to land development, or on constructed facilities and environmental planning. Other combinations are possible.

The program is administered by a committee of faculty representing the two departments. Applications are made directly to this committee through either department. The committee advises students on the choice of courses to meet their study objectives.

This is a combined degree. The diploma names only the S.B. in Planning, but a letter provided upon graduation by the Combined Program Committee confirms the student's participation in the program.

1
A computer-related subject such as 1.00 Introduction to Computers and Engineering Problem Solving is suggested as one subject.

Bachelor of Science in Planning Course XI — Option 2

Degree requirements applicable to the Class entering MIT in 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by 1.01J in the Departmental Program][1]	8
Science Distribution Requirement [2 subjects can be satisfied by 1.00 and 18.03 in the Departmental Program]	3
Laboratory Requirement[2]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 72

- 1.00 Introduction to Computers and Engineering Problem Solving, 12
- 1.01J Engineering Aspects of Economic Analysis, 12
- 1.02 Optimal Design of Engineering Systems, 12
- 1.03 Introduction to Probability and Statistics for Engineers, 12; 18.03

One of the following two subjects:

- 11.001 Introduction to Urban Design and Development, 12
- 11.002 Introduction to Public Policy Analysis and Government Action, 12

plus

- 18.03 Differential Equations, 12; 18.02**

Planned Electives: 72

Including:

Subjects which assure breadth and depth in the area of specialization (at least 18 units)

Civil Engineering subjects (at least 18 units)

A special studies project or thesis which requires a synthesis of knowledge within the scope of the joint program (at least 12 units)

Units in Departmental Program that also satisfy the General Institute Requirements (36)

Unrestricted Electives 72

Total Units Required for the S.B. Degree Beyond the General Institute Requirements 180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

1
Up to 27 additional units of unrestricted electives may be obtained if three of the planned electives in the Departmental Program are designated as the student's Field of Concentration.
2
Suggested subject — 11.188

Bachelor of Science in Planning Course XI — Option 3 Urban and Regional Planning in Developing Countries

This option provides training in urban studies and planning in the setting of developing countries. It is designed particularly for those students who come from developing countries or who are preparing to work in such places.

Students electing this option must take one of the two introductory subjects offered by the Department, the Urban Studies laboratory, and the thesis; and a set of subjects in issues of regional development, and the politics, economics, and social aspects of development. Electives are chosen in conference with the student's advisor and are intended to develop a basic competence in analysis and planning in some specific areas.

The major problem area foci available are housing, transportation, and urban policy, but arrangements can be made to combine work in other departments such as Architecture, Civil Engineering, Economics, or Political Science.

Five-Year S.B.-M.C.P. Option

MIT undergraduate planning majors may apply for admission to the Department's Master in City Planning (M.C.P.) Program at the end of their junior year. Students accepted into the five-year program are exempted from the undergraduate thesis requirement and receive both the Bachelor of Science and the Master in City Planning at the end of five years. Admission is limited to those undergraduates who have demonstrated exceptional professional promise. More information on the five-year program can be obtained from the Director of the Undergraduate Urban Studies Program or the Chairman of the M.C.P. Committee.

Bachelor of Science in Planning Course XI — Option 1

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program, plus three Humanities Distribution subjects totaling	27
Science Distribution Requirement[1]	36

Laboratory Requirement can be satisfied by 11.188 or 17.203 in the Departmental Program.

Departmental Program	

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 100-114

Group I: Introduction

One of the following two subjects:

- 11.001 Introduction to Urban Design and Development, 12
- 11.002 Introduction to Public Policy Analysis and Government Action, 12

Group II: Social Science

- 11.005 Urban Social Structure and Process, 9
- 11.007J Politics and Public Policy, 12
- 14.01 Principles of Microeconomics, 9

Group III: Planning and Applied Social Research

- 11.003 Planning and Applied Social Research I, 12; 11.007J, 14.01
- 17.203 Political Science Laboratory, 12
- 11.188 Social Research Methods, 12
- 6.041 Probabilistic Systems Analysis, 12

Group IV: Senior Project

Senior Project (10-24 units)

Planned Electives: at least 45

A coherent selection of five subjects in planning and applied social science developed in consultation with the student's departmental advisor. The student must include at least one additional social science subject such as 11.008J Economic Structure of Cities or 11.014J American Urban History II; at least 12 units of approved internship, fieldwork, or workshop experience; and at least three subjects comprising an approved area of specialization (described in text).

Unrestricted Electives 78-92

Total Units Required for the S.B. Degree 360

1
A computer-related subject such as 1.00 Introduction to Computers and Engineering Problem Solving is suggested as one subject.

Graduate Study

Bachelor of Science in Planning
Course XI — Option 2

Degree requirements to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by 1.01J in the Departmental Program, plus appropriate subjects totaling[1]	63
Science Distribution Requirement can be satisfied by 1.00 and 18.03 in the Departmental Program, plus appropriate subjects totaling	12
Laboratory Requirement[2]	12

Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		72
1.00	Introduction to Computers and Engineering Problem Solving, 12	
1.01J	Engineering Aspects of Economic Analysis, 12	
1.02	Optimal Design of Engineering Systems, 12	
1.03	Introduction to Probability and Statistics for Engineers, 12; 18.03	
	One of the following two subjects:	
11.001	Introduction to Urban Design and Development, 12	
11.002	Introduction to Public Policy Analysis and Government Action, 12	
	plus	
18.03	Differential Equations, 12; 18.02*	
Planned Electives:		**at least 72**
Including:		
Subjects which assure breadth and depth in the area of specialization (at least 18 units)		
Civil Engineering subjects (at least 18 units)		
A special studies project or thesis which requires a synthesis of knowledge within the scope of the joint program (at least 12 units)		
Unrestricted Electives[1]		**at least 69**
Total Units Required for the S.B. Degree		**360**

*Alternate prerequisites are listed in the subject description.

1
Up to 27 additional units of unrestricted electives may be obtained if three of the planned electives in the Departmental Program are designated as the student's Field of Concentration.
2
Suggested subject — 11.188

The Department of Urban Studies and Planning offers graduate work leading to the Master in City Planning and the Doctor of Philosophy. The Course is open to students with varying backgrounds. Urban studies, environmental studies, architecture, political science, civil engineering, economics, sociology, law, management, geography, and public administration all offer suitable preparation. Applicants from other fields are also accepted. Undergraduate preparation for urban studies and planning usually differs from that required for scientific degrees at MIT. Further information concerning academic programs in the Department, admissions, and financial aid may be obtained from the Graduate Admissions Coordinator, Room 7-333, MIT, (617) 253-2028.

Master in City Planning

The basic professional degree in the planning field is the Master in City Planning (M.C.P.). The Department of Urban Studies and Planning provides graduate education for men and women who assume professional roles in public and private agencies, in the United States and abroad. The Department seeks to provide M.C.P. students with the skills and specialized knowledge needed to fill traditional as well as emerging planning roles.

The two-year M.C.P. Program emphasizes the mastery of the tools necessary for effective practice and is therefore distinct from liberal arts programs in urban affairs. An intensive course of study stresses skills for policy analysis and institutional intervention. The Master's Program is recognized by the American Planning Association.

The M.C.P. program offers professional training mainly within the context of the institutional processes and cultural values of more developed countries, and is described in the following paragraphs. For those students from developing areas of the world or for those with a primary interest in such areas, a modified option is available, summarized in the subsequent section on Master in City Planning for Developing Areas. Because the M.C.P./DA program has a departmental admissions process that explicitly takes into account educational backgrounds and professional experience acquired abroad, applicants must specify interest in the M.C.P./Developing Areas option on their application forms if they wish to be admitted to that program.

A student's plan of study in the M.C.P. program is set forth in a program statement developed jointly by the student and faculty advisor. The program statement describes the purposes and goals of study, the proposed schedule of subjects, the manner in which competence in a specialization is developed, and an indication of a possible thesis project topic. The program statement is submitted at the end of the first semester of study to the M.C.P. Committee, which monitors each student's progress.

Degree Requirements. Students are expected to take a minimum of 30 credit units each term (about three subjects) or a minimum of 120 total units, in addition to the thesis.

The Professional Core. Three subjects, taught in conjunction with each other during the student's first term in the Department, constitute a "core experience" that we view as central to the professional program. The core subjects are:

11.200 Planning and Institutional Processes, 11.206 Core Practicum, 11.210 Political Economy for Planners I, and 11.220 Quantitative Reasoning and Statistical Methods for Planning, and are described in Chapter VIII.

It is possible to test out of 11.210 and 11.220, (not 11.200); the exams also serve to diagnose students' own strengths and weaknesses.

M.C.P. students select an area of **specialization** by the end of the first semester, tailored to individual students' interests. Specializations at the M.C.P. level include:

Design and Development combines the traditional area of environmental design and real estate development. This specialization involves conceptualizing, guiding, and implementing changes in the spatial environment. Work in environmental design involves acquiring knowledge about the interactions between people and the settings they inhabit; understanding the historical evolution of current forms of settlement; learning methods for analyzing, programming, designing, and implementing environmental change; anticipating and coping with the impacts of changes in the form and functioning of human settlements; and developing processes for regulating and managing environments over time. **Real Estate Development** focuses on the planning and management of urban development, and especially on design, location, and financing.

Emphasis is on analysis of the financial dimensions of real estate, public policies that affect private development, incentives in the development sector, land use regulations, and assessment of markets and housing needs. Public-private partnerships for real estate development construction issues, and the operation of financial markets are other important subjects. Students may elect to pursue subjects offered as part of the Real Estate Development Program, which is described in Chapter VI.

Environmental Planning and Policy emphasizes the study of the legal, institutional, and economic tools by which society conserves and manages its environmental resources. Substantive areas of concern include energy facility siting, pollution control, land use, growth management, and coastal zone management. Students examine the interactions between built and natural systems, techniques for describing and evaluating changes in environmental quality, approaches to environmental policy analysis, and mechanisms for assessing the choices posed by the environmental impacts of new technology.

Housing and Community Development integrates economic, social, and political theories of development with planning and implementation methods. While the development of the whole community is necessary, the emphasis is on the delivery and provision of housing and employment. Studies include national and local housing employment policies; legislative, administrative, and private institutions; and financial analysis of public programs and private capital. Other studies include the impact of housing, capital, and labor markets on the operation of the local economy; strategies for intervening in neighborhood income and employment structures; analysis of current and alternative policies toward neighborhoods; and the development of new techniques for defining community needs, assessing alternative policies, and implementing planned change.

The department cooperates with several departments at MIT in teaching and research in **Transportation Planning.** Coordination is provided by the Center for Transportation Studies described in Chapter VI. Topics of special interest include transportation systems analysis, transportation policy studies, transportation technology assessment, and the management of transportation enterprise. A number of faculty members and students are interested in the relationship between transportation and particular problems, such as regional development, urbanization, and the pricing of commodities. Work spans developed and less developed countries.

All students are required to submit a **thesis** on a topic of their choice. The Department encourages M.C.P. students to avoid the traditional perception of the thesis as a "minidissertation," and to think instead of a client-oriented, professional document, which bridges academic and professional concerns. While most of the thesis work occurs during the last semester of the second year, students are urged to begin the process of defining a thesis topic early in the second year.

Students in the M.C.P. Program are encouraged to integrate **fieldwork and internships** with academic course work. The Department provides a variety of individual and group field placements involving varying degrees of faculty participation and supervision. Academic credit is awarded for field experience, although some students choose instead to participate in the work-study financial aid program. The Department also sponsors a variety of seminars in which students have an opportunity to reflect on their field experiences.

Master of City Planning/Developing Areas Option

The requirements for this professional degree option are similar to the regular M.C.P. program. However, while the core and specialized subjects of the regular program tend to emphasize practice in developed countries, the M.C.P./DA program places greater weight upon cultural and institutional comparisons and on the planning skills for regional and area growth and development in Asia, the Middle East, Africa, Latin America, and the Caribbean region. Regional Development involves the study of economic growth and locational change. Emphasis is on the production and distribution of goods and services; job creation and employment processes; development finance, trade, migration, and capital flows; techniques for analyzing regional development; and the evaluation of international regional economic policies. Currently, special attention is paid to the application of regional input-output techniques. Students with an interest in the development problems of disadvantaged regions in the United States, Canada, Europe, and Japan should apply to the regular M.C.P. program.

As an alternative to the core subject, 11.200 Planning and Institutional Processes, students in the M.C.P./DA option are required to take 11.205 Planning Roles and Institutions in Developing Countries, which stresses the role of institutions in shaping planning processes in third world countries. Students may test out of the other two required core subjects, 11.210, and 11.220, as described earlier. For some specializations under the M.C.P./DA option (indicated by a * in the following paragraph), additional economics or quantitative methods courses may be required after review of the student's prior course work and diagnostic test results.

Possibilities for specialization under the M.C.P./DA option include: Planning Process and Implementation, National and Subnational Area Development Problems and Policy, Regional Economic Theory and Planning,* Transportation and Urban Infrastructure,* Housing Problems and Policy, Urban Settlement Planning, and Urban Economics and Public Finance.* It is also possible to construct specializations in environmental design, real estate, and land management.

Simultaneous Master's Degrees in City Planning and Architecture

Students who have been admitted to either the Department of Urban Studies and Planning or the Department of Architecture are invited to propose programs for joint work in the two fields leading to degrees in both fields. Degree combinations may be M.C.P.-M.Arch. or M.C.P.-S.M.Arch.S. Program proposals must be made prior to the student's final academic year in the first degree program and are considered during the spring admissions process. Normally, students are expected to meet the core requirements of both degrees, but may submit a joint thesis and count some subjects completed for one degree towards the other, thus decreasing the overall time required for the two degrees.

Double degree programs may include an innovative combination of work in any of the fields of specialization of the two departments. They may represent preparation for professional roles that bridge the two fields or the definition of new roles that are needed but not yet defined. Students pursuing dual degrees work with advisors in both departments.

Simultaneous Master's Degrees in City Planning and Transportation

Students who have been admitted to study for the Master of City Planning or the Master of Science in Transportation are invited to propose programs for joint work leading to Master's degrees in both fields. The details of this program are described in Chapter VI under the Center for Transportation Studies.

Emphasis is on analysis of the financial dimensions of real estate, public policies that affect private development, incentives in the development sector, land use regulations, and assessment of markets and housing needs. Public-private partnerships for real estate development construction issues, and the operation of financial markets are other important subjects. Students may elect to pursue subjects offered as part of the Real Estate Development Program, which is described in Chapter VI.

Environmental Planning and Policy emphasizes the study of the legal, institutional, and economic tools by which society conserves and manages its environmental resources. Substantive areas of concern include energy facility siting, pollution control, land use, growth management, and coastal zone management. Students examine the interactions between built and natural systems, techniques for describing and evaluating changes in environmental quality, approaches to environmental policy analysis, and mechanisms for assessing the choices posed by the environmental impacts of new technology.

Housing and Community Development integrates economic, social, and political theories of development with planning and implementation methods. While the development of the whole community is necessary, the emphasis is on the delivery and provision of housing and employment. Studies include national and local housing employment policies; legislative, administrative, and private institutions; and financial analysis of public programs and private capital. Other studies include the impact of housing, capital, and labor markets on the operation of the local economy; strategies for intervening in neighborhood income and employment structures; analysis of current and alternative policies toward neighborhoods; and the development of new techniques for defining community needs, assessing alternative policies, and implementing planned change.

The department cooperates with several departments at MIT in teaching and research in **Transportation Planning.** Coordination is provided by the Center for Transportation Studies described in Chapter VI. Topics of special interest include transportation systems analysis, transportation policy studies, transportation technology assessment, and the management of transportation enterprise. A number of faculty members and students are interested in the relationship between transportation and particular problems, such as regional development, urbanization, and the pricing of commodities. Work spans developed and less developed countries.

All students are required to submit a **thesis** on a topic of their choice. The Department encourages M.C.P. students to avoid the traditional perception of the thesis as a "minidissertation," and to think instead of a client-oriented, professional document, which bridges academic and professional concerns. While most of the thesis work occurs during the last semester of the second year, students are urged to begin the process of defining a thesis topic early in the second year.

Students in the M.C.P. Program are encouraged to integrate **fieldwork and internships** with academic course work. The Department provides a variety of individual and group field placements involving varying degrees of faculty participation and supervision. Academic credit is awarded for field experience, although some students choose instead to participate in the work-study financial aid program. The Department also sponsors a variety of seminars in which students have an opportunity to reflect on their field experiences.

Master of City Planning/Developing Areas Option

The requirements for this professional degree option are similar to the regular M.C.P. program. However, while the core and specialized subjects of the regular program tend to emphasize practice in developed countries, the M.C.P./DA program places greater weight upon cultural and institutional comparisons and on the planning skills for regional and area growth and development in Asia, the Middle East, Africa, Latin America, and the Caribbean region. Regional Development involves the study of economic growth and locational change. Emphasis is on the production and distribution of goods and services; job creation and employment processes; development finance, trade, migration, and capital flows; techniques for analyzing regional development; and the evaluation of international regional economic policies. Currently, special attention is paid to the application of regional input-output techniques. Students with an interest in the development problems of disadvantaged regions in the United States, Canada, Europe, and Japan should apply to the regular M.C.P. program.

As an alternative to the core subject, 11.200 Planning and Institutional Processes, students in the M.C.P./DA option are required to take 11.205 Planning Roles and Institutions in Developing Countries, which stresses the role of institutions in shaping planning processes in third world countries. Students may test out of the other two required core subjects, 11.210, and 11.220, as described earlier. For some specializations under the M.C.P./DA option (indicated by a * in the following paragraph), additional economics or quantitative methods courses may be required after review of the student's prior course work and diagnostic test results.

Possibilities for specialization under the M.C.P./DA option include: Planning Process and Implementation, National and Subnational Area Development Problems and Policy, Regional Economic Theory and Planning,* Transportation and Urban Infrastructure,* Housing Problems and Policy, Urban Settlement Planning, and Urban Economics and Public Finance.* It is also possible to construct specializations in environmental design, real estate, and land management.

Simultaneous Master's Degrees in City Planning and Architecture

Students who have been admitted to either the Department of Urban Studies and Planning or the Department of Architecture are invited to propose programs for joint work in the two fields leading to degrees in both fields. Degree combinations may be M.C.P.-M.Arch. or M.C.P.-S.M.Arch.S. Program proposals must be made prior to the student's final academic year in the first degree program and are considered during the spring admissions process. Normally, students are expected to meet the core requirements of both degrees, but may submit a joint thesis and count some subjects completed for one degree towards the other, thus decreasing the overall time required for the two degrees.

Double degree programs may include an innovative combination of work in any of the fields of specialization of the two departments. They may represent preparation for professional roles that bridge the two fields or the definition of new roles that are needed but not yet defined. Students pursuing dual degrees work with advisors in both departments.

Simultaneous Master's Degrees in City Planning and Transportation

Students who have been admitted to study for the Master of City Planning or the Master of Science in Transportation are invited to propose programs for joint work leading to Master's degrees in both fields. The details of this program are described in Chapter VI under the Center for Transportation Studies.

School of Engineering

Aeronautics and Astronautics (Course 16)
Chemical Engineering (Course 10)
Civil Engineering (Course 1)
Electrical Engineering and Computer Science (Course 6)
Materials Science and Engineering (Course 3)
Mechanical Engineering (Course 2)
Nuclear Engineering (Course 22)
Ocean Engineering (Course 13)



In this age of accelerating technological advances, coupled with increasingly scarce and expensive resources, the profession of engineering is occupying an increasingly important role, both in creating the complex systems society needs and wants and in ensuring that these systems meet societal goals for the human environment. Never have the challenges and opportunities for careers in engineering been more exciting or more promising than they are today.

Engineering is a creative profession concerned with developing and applying scientific knowledge and technology to meet societal needs within physical, economic, human, political, legal, and cultural constraints.

The growing influence of technology on all the functions of society such as energy and natural resource production, manufacturing and materials processing, health care and human rehabilitation, information, education, defense, construction, and transportation have created a large demand for engineering graduates, not only to enter the professional practice of engineering, but to bring the strengths of an engineering education to related fields such as law, medicine, management, and government.

The primary objectives of the School of Engineering at MIT are to educate and prepare men and women for leadership in industry, government, and educational institutions; to advance the knowledge base of the engineering professions; and to influence the future directions of engineering education and practice.

The educational programs in the School emphasize the understanding of fundamental principles; facility with experimental, computational, and analytical methods; development of skill in the creative processes of engineering such as design; and the development of a self-confidence and versatility of mind that prepare the individual for a lifetime of learning and professional growth.

The academic departments in the School provide the primary homes for faculty, students, and degree programs, and provide continuity and stability for the basic engineering disciplines. However, the departments increasingly share common interests in the broad areas of application to which their individual disciplines and technologies apply. Among the major applications of concern in most of the engineering departments are energy supply, conversion, and conservation; transportation (air and space, ocean, urban, rail, and automotive); communication and information processing (including computer design and utilization); manufacturing and processing; construction; materials and the extraction and

processing of natural resources; environmental issues; and biomedical engineering and biotechnology. The approximately 35 interdepartmental centers, laboratories, and programs in which the School is involved provide the mechanisms and facilities for faculty and students to undertake collaborative research and engage in educational programs dealing with these and other interdisciplinary applications of importance to society. Many of these are described in Chapter VI.

Through its departments and various interdepartmental groups, the School of Engineering offers a wide variety of educational programs. Large numbers of undergraduate students often enroll in some graduate subjects, and all students are strongly encouraged to participate in a variety of research, engineering applications, and public service projects. Together, these activities and interactions provide a rich educational experience.

The School of Engineering offers formal **graduate degree programs** in both the departmental areas and a number of interdepartmental areas including Biomedical Engineering, Environmental Studies, Instrumentation, Operations Research, Materials, Mineral Resources Engineering and Management, Technology and Policy, and Management of Technology. In addition, numerous other interdepartmental opportunities exist at both the undergraduate and graduate levels. With the faculty and resources of all the departments available, the student is able to develop a program that satisfies his or her own intellectual and professional objectives. The student interested in an interdepartmental program will find it helpful to study the departmental descriptions as well as to read the specific sections in Chapter VI covering interdepartmental opportunities that combine disciplines from MIT's four other Schools with those of the School of Engineering.

Undergraduate degrees are awarded by the departments of the School but can embrace several interdepartmental fields as well. Several departments also offer "undesignated" degrees, which lead to the Bachelor of Science without departmental designation. The curricula for these programs offer students opportunities to pursue programs of studies that are broader than could be accommodated within a normal four-year departmental program.

Most undergraduate departmental degree programs in the School are accredited by the Accreditation Board for Engineering and Technology. However, given their more general nature, accreditation has not been sought for any undesignated degree programs. Holders of an accredited-program degree can generally take examinations for professional registration with fewer years of experience than holders of unaccredited or non-engineering program degrees. Also, an accredited degree may be required for certain jobs. As the situation varies markedly from field to field, students should discuss the question of accreditation with their faculty advisors when considering undesignated degree programs.

For undergraduates, the first-year curriculum encompasses study of physics, chemistry, mathematics, and humanities/social sciences, while still offering students many opportunities to make contact with engineering through undergraduate seminars, research opportunities, and elective subjects. In the second year, students typically continue these studies with subjects leading toward the fulfillment of the Science Distribution; Laboratory; and Humanities, Arts, and Social Sciences requirements. An undergraduate student normally becomes affiliated with a particular department as early as the beginning of the sophomore year, and from that time on works closely with an advisor from that department or program. Alternatively, a student may elect to delay this choice until the start of the junior year without necessarily delaying graduation beyond four years.

However, a student with an interest in engineering is encouraged to become involved with one of the engineering departments even during the freshman year, for example, through the Undergraduate Research Opportunities Program or the Undergraduate Seminar Program.

Many opportunities exist for individual initiatives. For example, significant numbers of students find it possible to combine their primary undergraduate degrees with a second undergraduate degree in another area, such as management, political science, economics, one of the sciences, or another area of engineering. Others organize their programs so as to receive undergraduate and graduate degrees simultaneously. Completion of the undergraduate degree requirements in less than four years is also possible in some cases.

The School also offers an extensive program in **continuing education** through the Center for Advanced Engineering Study. Its goal is to improve the capabilities and effectiveness of practicing engineers. Priority is given to advancing the arts and sciences of applications, rather than remedial instruction, in both technical and managerial-technical areas. Further details on this interdepartmental program may be found in Chapter VI.

Engineering Internship Program

The Engineering Internship Program is nationally recognized for its excellence. It combines traditional on-campus academic programs with off-campus work experience in industry and government. Such experience can be an important aspect of a sound engineering education and can also help students make more informed choices among the on-campus educational offerings, as well as obtain a better understanding of career opportunities available to them after graduation.

The Engineering Internship Program is similar to the VI-A Internship Program in the Department of Electrical Engineering and Computer Science.

Emphasis is placed on ensuring that students in the program are placed in rewarding "real-world" company assignments that extend the learning experience into areas that are not available at MIT. There is extensive faculty participation and advising in both the on- and off-campus components of the program.

The Engineering Internship Program is designed principally as a joint undergraduate and graduate program that leads to the simultaneous award of the S.B. and S.M. degrees in an engineering department upon successful completion of all degree requirements.

Programs have been established in the Departments of Aeronautics and Astronautics (XVI-C), Civil Engineering (I), Electrical Engineering and Computer Science (VI), Materials Science and Engineering (III-B), Mechanical Engineering (II-B), Nuclear Engineering (XXII-A), and Ocean Engineering (XIII-C).

Program Description

The following general description is typical of most participating departments. Please see the listing in the appropriate department for unique features of each program.

Students normally enter the program in the summer after their sophomore year at MIT. Sophomores in good standing in the School of Engineering are eligible to apply for the program and must be selected by a participating company during the on-campus interview process.

The program consists of three work assignments at the same industrial firm or government agency. Work assignments of three months' duration each occur after the student's second year at MIT and one after the third year. During the first term of the fourth year, a student applies to the department for

admission into the graduate program. For those students who are accepted to the graduate program, there is one additional work assignment of seven months' duration after the fourth year. Additional or substitute work assignments are possible.

For those students who are not admitted to the departmental graduate program or do not continue on to graduate school for other reasons, the Internship Program will terminate at the end of the spring term of the fourth year at the S.B. level.

Students who are accepted to the graduate program will often do a combined S.B.-S.M. thesis on a topic related to their work assignment. Usually, for such a thesis, the research will be performed primarily in-plant during the final work assignment, under the combined supervision of company staff and an MIT faculty member.

Students are paid during their periods of residence at the participating companies and should expect to receive a travel allowance. There are no obligations on either side regarding further employment.

Further information on the program may be obtained from the department of registration or from John R. Martuccelli, Director, Engineering Internship Program, MIT, Room 1-211, Cambridge, Massachusetts 02139, (617) 253-8051.

School-Wide Electives

The School of Engineering offers a set of School-Wide subjects, each of which is of interest to students from a number of departments in the School. A School-Wide subject may: 1) integrate knowledge from several disciplines and illustrate the commonality of the intellectual underpinnings of the departments in the School of Engineering, 2) be at the interface between the academic program of the School of Engineering and the programs of other Schools at MIT, 3) be a service subject to engineering students and other students, and 4) be germane to many engineering students, without being central to any one departmental program. A list of current School-Wide Electives follows. Please note that registration for these subjects takes place through one of the departmental numbers. Subject descriptions may be found at the end of the subject description chapter of this catalogue.

Computer Models of Physical and Engineering Systems U(2) SD
1.12, 2.101, 3.05, 10.11, 13.51, 16.008, 22.006

Engineering Risk-Benefit Analysis (A) G(2)
1.155, 2.943, 3.577, 6.938, 10.816, 13.621, 16.794, 22.82

Engineering Systems Analysis (A) G(1)
1.146, 2.192, 3.56, 13.62, 16.784, 22.821, TPP 21

Entrepreneurship G(2)
2.942, 3.566, 6.936, 10.801, 13.78, 16.672, 22.86

Introduction to Technology and Law U(1)
1.165, 2.998, 13.97, 16.792, 22.085

Inventions and Patents U(1)
3.172, 6.901, 16.673, 22.084

Management in Engineering U(1)
2.96, 6.930, 10.806, 13.52, 16.993, 22.002

Nuclear War: Threat and Avoidance U(2) HASS
6.934, 8.208, 13.91, 16.994, 17.465, 22.003, STS 051

Nuclear Weapons and Arms Control: Technology and Policy Issues G(1)
6.932, 13.93, 16.995, 17.486, 22.841

Optimal Design of Engineering Systems U(1)
1.02, 6.940, 13.671

Probabilistic Models in Engineering U(2)
1.06, 6.939, 13.672, 16.793

Office of the Dean

Gerald Loomis Wilson, Sc.D.
Vannevar Bush Professor
Professor of Electrical and Mechanical Engineering
Dean

Jack Leo Kerrebrock, Ph.D.
Richard Cockburn Maclaurin Professor of Aeronautics and Astronautics
Associate Dean

Eric Johnson, S.B., M.S.
Assistant Dean for Resource Development

Donna R. Savicki, B.S., M.S.
Assistant Dean for Administration

G. Rodger Crowe, B.S., M.B.A.
Director of Development

(To be appointed)
Director, Engineering Internship Program

Pamela Hart, B.A.
Administrative Officer

School Professors Without Departmental Affiliation

Judah Leon Schwartz, Ph.D.
Professor of Engineering Science and Education

Nicholas A. Ashford, Ph.D.
Associate Professor of Technology and Policy

Lawrence L. Bucciarelli, Ph.D.
Associate Professor of Engineering and Technology Studies

James M. Utterback, Ph.D.
Associate Professor of Engineering
Director, Industrial Liaison Program

Professors Emeriti

Alfred Adolf Heinrich Keil, Dr.Rer.Nat.
Professor of Ocean Engineering, Emeritus
Ford Professor of Engineering, Emeritus

Myron Tribus, Ph.D.
Professor of Engineering, Emeritus

Department of Aeronautics and Astronautics

Eugene Edzards Covert, Sc.D.
Professor of Aeronautics and Astronautics
Head of the Department

Professors

Judson Richard Baron, Sc.D.
Professor of Aeronautics and Astronautics

John Dugundji, Sc.D.
Professor of Aeronautics and Astronautics

Shaoul Ezekiel, Sc.D.
Professor of Aeronautics and Astronautics and Electrical Engineering
Director, Center for Advanced Engineering Study

Edward Marc Greitzer, Ph.D.
H. Nelson Slater Professor of Aeronautics and Astronautics

Norman Douglas Ham, Sc.D.
Professor of Aeronautics and Astronautics

Walter Mark Hollister, Sc.D.
Professor of Aeronautics and Astronautics

Karl Uno Ingard, Ph.D.
Professor of Aeronautics and Astronautics and Physics

Jack Leo Kerrebrock, Ph.D.
Richard Cockburn Maclaurin Professor of Aeronautics and Astronautics
Associate Dean, School of Engineering

Marten Teodor Landahl, Tekn.D.
Professor of Aeronautics and Astronautics
(On leave)

James Wah Mar, Sc.D.
Jerome Clarke Hunsaker Professor of Aerospace Education

Winston Roscoe Markey, Sc.D.
Professor of Aeronautics and Astronautics

James Elliot McCune, Ph.D.
Professor of Aeronautics and Astronautics

Earll Morton Murman, Ph.D.
Professor of Aeronautics and Astronautics
(On leave)

Amedeo Rodolfo Odoni, Ph.D.
Professor of Aeronautics and Astronautics and Civil Engineering
Codirector, Operations Research Center

Theodore Hsueh-Huang Pian, Sc.D.
Professor of Aeronautics and Astronautics

Robert Warren Simpson, Ph.D.
Professor of Aeronautics and Astronautics

Leon Trilling, Ph.D.
Professor of Aeronautics and Astronautics

Wallace Earl Vander Velde, Sc.D.
Professor of Aeronautics and Astronautics

Harold Yehuda Wachman, Ph.D.
Professor of Aeronautics and Astronautics

Sheila Evans Widnall, Sc.D.
Abby Rockefeller Mauzé Professor of Aeronautics and Astronautics

Laurence Retman Young, Sc.D.
Professor of Aeronautics and Astronautics

Associate Professors

Edward Francis Crawley, Sc.D.
Associate Professor of Aeronautics and Astronautics

Alan Harry Epstein, Ph.D.
Associate Professor of Aeronautics and Astronautics

Robert John Hansman, Jr., Ph.D.
Associate Professor of Aeronautics and Astronautics

Daniel Edgar Hastings, Ph.D.
Associate Professor of Aeronautics and Astronautics

Paul Alfred Lagace, Ph.D.
Associate Professor of Aeronautics and Astronautics

Manuel Martinez-Sanchez, Ph.D.
Associate Professor of Aeronautics and Astronautics
(On leave, spring)

Lena Valavani, Ph.D.
Associate Professor of Aeronautics and Astronautics

Assistant Professors

David Lee Akin, Sc.D.
Assistant Professor of Aeronautics and Astronautics

Harold Luchsingen Alexander, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Mark Drela, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Michael Bryce Giles, Ph.D.
Esther and Harold E. Edgerton Assistant Professor of Aeronautics and Astronautics

Michael Jeffrey Graves, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Steven Ray Hall, Ph.D.
Boeing Assistant Professor of Aeronautics and Astronautics

Belgacem Jery, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Andreas Hubertus von Flotow, Ph.D.
Charles Stark Draper Assistant Professor of Aeronautics and Astronautics

Visiting Professor

Omer Savas, Ph.D.
Associate Professor of Aeronautics and Astronautics

Adjunct Professors

Richard Horace Battin, Ph.D.
Adjunct Professor of Aeronautics and Astronautics

Rudrapatna V. Ramnath, Ph.D.
Adjunct Professor of Aeronautics and Astronautics

Senior Lecturers

Saul Sigmond Abarbanel, Ph.D.
Charles Oswald Cary
William Rede Hawthorne, Sc.D.
Yao Tzu Li, Sc.D.
René Harcourt Miller, M.A.
Robert Channing Seamans, Jr., Sc.D.
Edward Story Taylor, S.B.
Henry Philip Whitaker, S.M.
John Regnier Wiley, S.B.

Lecturers

Paul Jon Cefola, Ph.D.
John Jacob Deyst, Jr., Sc.D.
Donald Charles Fraser, Sc.D.
Betsy Gidwitz, Ph.D.
Stephen James Madden, Jr., Ph.D.
John Pascal Vinti, Sc.D.
Leonard Stephen Wilk, M.S.
Joseph Yamron, S.B.

Technical Instructors

Jeffrey Christopher DiTullio, B.S.
Allan Ralph Shaw
Edward Donald Weiner, A.S.E.E.

Administrative Officer

Helen Robbins Raine

Administrative Staff

Phyllis Anna Collymore, A.A.
Anne Marie Maynard
Elizabeth Zotos, B.A.

Senior Research Engineer

Charles McMaster Oman, Ph.D.

Principal Research Engineer

Choon Sooi Tan, Ph.D.

Research Associates

Robert David Bruen, M.S.
Robert Haimes, M.S.
James Francis Nash
Albert Thomas Supple, Jr., A.E.E.

Research Engineers

Raymond Anthony Ausrotas, M.S.
Peter Paul Belobaba, Ph.D.
Frank Herman Durgin, E.A.A.
Gerald Roger Guenette, Jr., Ph.D.
Dennis Francis Xavier Mathaisel, Ph.D.
John Demetrios Pararas, Ph.D.

Research Specialists

Paul H. Bauer, B.S.
Anne LaVin, B.S.
Carl Francis Varnerin, M.S.

Technical Assistant

Teva Regule, B.S.

Department of Aeronautics and Astronautics

(Course 16)

Postdoctoral Research Associate

Lisa A. Sievers, Ph.D.

Research Staff, Administrative

Ping Mai Lee
Holly Esther Rathbun, A.S.

Research Affiliates

James Draper, Ph.D.
Byron Kurt Lichtenberg, Sc.D.
Gregory Zacharias, Ph.D.

Visiting Engineers

Rudolphus Johannes A.W. Hosman, M.S.
Nobuko Mizumoto, M.S.
Sharon Newman, B.Sc.

Professors Emeriti

Joseph Bicknell, S.M.
Professor of Aeronautics and Astronautics, Emeritus

Robert Louis Halfman, S.M.
Professor of Aeronautics and Astronautics, Emeritus

Otto Carl Koppen, S.B.
Professor of Flight Vehicle Engineering, Emeritus

Elmer Eugene Larrabee, S.M.
Associate Professor of Aeronautics and Astronautics, Emeritus

Yao Tzu Li, Sc.D.
Professor of Aeronautics and Astronautics, Emeritus
Senior Lecturer

Walter McKay, S.M.
Professor of Aeronautics and Astronautics, Emeritus

René Harcourt Miller, M.A.
Professor of Aeronautics and Astronautics, Emeritus
Senior Lecturer

Robert Karl Mueller, Sc.D.
Associate Professor of Aeronautics and Astronautics, Emeritus

Robert Channing Seamans, Jr., Sc.D.
Professor of Aeronautics and Astronautics, Emeritus
Senior Lecturer

Edward Story Taylor, S.B.
Professor of Flight Propulsion, Emeritus
Senior Lecturer

Henry Philip Whitaker, S.M.
Professor of Aeronautics and Astronautics, Emeritus
Senior Lecturer

Emmett Atlee Witmer, Sc.D.
Professor of Aeronautics and Astronautics, Emeritus

Walter Wrigley, Sc.D.
Professor of Instrumentation and Astronautics, Emeritus

The primary goal of the Department of Aeronautics and Astronautics is to provide the best possible environment for the undergraduate and graduate education of aspiring young engineers. The undergraduate environment centers on the classroom, where experienced faculty teach the basic phenomenology that underlies the vehicle-oriented activities associated with Aeronautics and Astronautics. A broad scope of technology is required to design and develop such disparate air and space vehicles — ranging from "man-powered" to high-performance military aircraft; from manned or unmanned launch vehicles to satellites and space stations; or from vertical take-off and landing machines to trans-atmospheric or one-stage-to-orbit vehicles — yet a common knowledge lies in the scientific fundamentals and procedures for their application to specific missions. A basic foundation of this kind, followed by subjects treating special topics appropriate to a particular vehicle, provides our graduates with a background that aids their "life-long" education and maturation, and supports continued success in the increasingly complex and sophisticated profession of engineering.

Through research and consultation with industrial and governmental organizations, the faculty contributes to the Department's knowledge base and maintains an awareness of today's important technical issues and the implications of the application of phenomenology to the design and development of advanced vehicles and associated systems. No individual possesses sufficient insight to foresee all of the critical vehicles and their uses two decades from now, yet the underlying mathematical, physical, and chemical principles will not be altered drastically. Thus, today's student will be well served by learning fundamentals and acquiring learning skills in order to continue to learn as needed.

The Department is fortunate to have a faculty dedicated both to teaching and advising students and to conducting research. It is this combination of vehicle- or system-oriented teaching and research interests that provides a sense of excitement to both classroom and laboratory instruction. This statement is as true in sophomore classes as in the advanced, relatively specialized, disciplinary subjects for upperclass students.

Classroom activity is supplemented by laboratory exercises, a project laboratory, and a preliminary-design or systems-oriented class that is required for all students. Such activities expose young engineers to the complexities that exist when actual hardware is used, as compared with the idealization usually present in analytical activities. The design- or systems-

oriented subject in particular shows the interrelationship and compromises among the several disciplines when they are applied to a vehicle. This reinforces the lessons learned in Unified Engineering, and in the advanced, professional-level undergraduate subjects in Aeronautics and Astronautics.

The reports that are written by students describing their laboratory and project activities may also used to satisfy the MIT Writing Requirement. Undergraduates must also fulfill a Humanities, Arts, and Social Sciences Requirement to help them understand the era in which they live, and the effects of their work on the lives of others.

A central feature in this approach to education is that students learn how to learn, how to use basic principles to solve engineering problems (skills that will serve them well over an entire career), and how to foresee the consequences of their solutions and designs.

Using computers is a part of virtually every subject, from the standpoint of its utility as a tool through classroom instruction. Students naturally come to use it in homework assignments.

In addition to formal classroom and laboratory instruction, undergraduates are encouraged to participate in the research activities of the Department through the Undergraduate Research Opportunities Program. The various research opportunities available to graduate students are outlined under Graduate Study.

The graduate educational environment combines the classroom and the laboratory. As the students proceed from the Master's to the Doctoral Program, the laboratory, in the broadest use of the term, becomes the focus for learning. This focus occurs naturally as an outcome of the faculty's research interests.

Aero/Astro graduate education is characterized by continued attention to basic phenomena associated with the disciplines being studied. A thorough grounding knowledge is provided through classroom and laboratory exercises, as well as through the experience gained by coping with unstructured problems, creating the flexibility needed for a long and successful career, both within and beyond the sphere of Aeronautics and Astronautics.

The graduate teaching and research activities of the Department are strongly interwoven. Graduate subjects evolve from the research and professional interests of the faculty and, in turn, serve to introduce students to the areas of active research. Teaching activities are informally organized into six divisions of instruction: Mechanics and Physics of Fluids; Structures, Materials, and Aeroelasticity; Propulsion and Energy Conversion; Instrumentation, Guidance, and Control; Biomedical Engineering; and Aeronautical and Astronautical Systems. Research is conducted in several departmental laboratories, each of which is described briefly in the section on Graduate Study. In addition, the Department maintains close interaction with the Charles Stark Draper Laboratory.

Undergraduate Study

Bachelor of Science in Aeronautics and Astronautics
Course XVI

Undergraduate study in the Department leads to the Bachelor of Science in Aeronautics and Astronautics at the end of four years. The curricula provide flexibility to meet the needs of professionals in aerospace activities ranging from fundamental research to responsible engineering direction of large enterprises.

The required undergraduate curriculum provides a core around which the student can build — either to become a practicing engineer upon receipt of the S.B. or to continue on to graduate studies in any of the specialties. It includes: 1) a fall-spring sequence of subjects called Unified Engineering I-IV, 2) a set of Advanced Required Subjects, 3) an Experimental Projects Laboratory, and 4) a Systems Engineering subject.

Unified Engineering is offered in sets of two 12-unit subjects in two successive semesters. These subjects are taught cooperatively by a number of faculty members. Their purpose is to introduce new students to the disciplines and methodologies of aerospace engineering at a basic level, with a balanced exposure to analysis, empirical methods, and design. The areas covered include statics, dynamics, structures, fluid mechanics, thermodynamics, propulsion, control, and systems engineering. Several laboratory experiments are performed and a number of systems problems which interrelate the disciplines are included.

Unified Engineering is usually taken in the sophomore year; it fulfills the prerequisites for a variety of Advanced Required Subjects and Electives which deal more intensively with subjects in the six main areas of Aeronautics and Astronautics described in the introduction to the Department. Alternatively, a student may take Unified Engineering in the junior year, and complete the Departmental requirements in the senior year; this also provides a well-rounded engineering education and excellent preparation for graduate study.

The Advanced Required Subjects treat more completely and in greater depth the material to which the student is introduced in Unified Engineering and in the other basic required subjects. To ensure adequate breadth of preparation in each student's education, a distribution from among the undergraduate subjects is required.

Each student has the opportunity in the **Undergraduate Projects Laboratory** (16.622) to conceive, organize, and execute an individual experimental project under the supervision of a faculty member. A proposal is prepared; oral and written reporting of the results are required. The written project reports are critically reviewed for writing style and exposition by faculty from the School of Humanities and Social Science.

The **Systems Engineering** subject requires students, as a team, to pull together their undergraduate education through the design of an operating system such as a manned space station or a vertical takeoff airplane. For maximum benefit, students should complete 16.02 *and* 16.54 before taking 16.84, or 16.20 *and* 16.53 before taking 16.85.

To take full advantage of the unique research environment of MIT, undergraduates are encouraged to become involved in the research activities of the Department through UROP, the Undergraduate Research Opportunities Program. Many of the faculty actively seek undergraduates to become a part of their research team. Specific areas of research opportunity are outlined under Graduate Study. It also should be noted that the advanced undergraduate student, through careful selection and scheduling of the elective freedom, can progress to graduate subjects in one or more areas of interest.

The Department recommends 1) that either 3.091 or 5.11 be used to satisfy the Institute Chemistry Requirement, 2) that an introductory digital computing programming subject such as 1.00, 2.10, or 6.001 be taken as early as possible, and 3) that 21.780 Scientific and Engineering Writing be taken as part of the Humanities, Arts, and Social Sciences Requirement.

Any one of several programs leads to the degree of Bachelor of Science in Aeronautics and Astronautics, and all are accredited by the Accreditation Board for Engineering and Technology. If desired, the student may request an unspecified degree, Bachelor of Science. This degree is not so accredited.

Program 1 Aeronautical and Astronautical Engineering. Program 1 is appropriate for students desiring a broad exposure to aerospace engineering in the normal four years of residence at MIT. The required subjects may be supplemented with additional advanced undergraduate subjects or graduate subjects according to individual interests. Further details on concentrations in the six main areas of Aeronautics may be obtained from the Department.

Bachelor of Science in Aeronautics and Astronautics
Course XVI
Program 1 Aeronautical and Astronautical Engineering

Degree requirements applicable to the Class entering in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [only two of these three subjects can be satisfied from among 6.071, 8.03, 18.03, and 16.001 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 16.622 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Basic Required Subjects:	96
3.094 Materials Technology, 12	
6.071 Introduction to Electronics, 12; 18.01, *8.02*	
8.03 Physics III, 12; 8.02**, 18.02	
16.001 Unified Engineering I, 12; 8.01, *18.03*	
16.002 Unified Engineering II, 12; 8.01, *18.03*	
16.003 Unified Engineering III, 12; 16.001, 16.002	
16.004 Unified Engineering IV, 12; 16.001, 16.002	
18.03 Differential Equations, 12; 18.02**	
Advanced Required Subjects:	75
One of the following two subjects:	
16.02 Aerodynamics, 12; 16.004**	
16.06 Molecular Gas Dynamics of Space and Re-entry, 12; 16.004**	
plus	
16.20 Structural Mechanics, 12; 16.004**	
16.30 Principles of Automatic Control, 12; 18.03	
One of the following two subjects:	
16.53 Rocket Propulsion, 12; 16.004	
16.54 Aircraft Engines and Gas Turbines, 12; 16.004	
plus	
16.621 Experimental Projects I, 3; 16.004	
16.622 Experimental Projects II, 12; 16.621	
One of the following two subjects:	
16.84 Flight Vehicle Engineering, 12; 16.02**	
16.85 Space Systems Engineering, 12; 16.20	
Units in Departmental Program that also satisfy the General Institute Requirements	(36)
Unrestricted Electives	48
Total Units Required for the S.B. Degree beyond the General Institute Requirements	183

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Program 2 Aeronautical and Astronautical Engineering: Avionics Option.

The Avionics Option prepares the student for a career in Aerospace Electronics. It also provides a strong foundation for graduate work in the fields of Instrumentation, Guidance, and Control. The program is designed for students who are interested in the application of electronics to guidance, navigation, surveillance/stabilization, instrumentation, and control of aircraft or spacecraft. New graduates traditionally have joined this professional area after having had an undergraduate major in electrical or aeronautical engineering, and having been introduced to the other half of their discipline through apprenticeship or graduate study. This option allows the student to learn the basics of both parts of the discipline as an undergraduate. The requirements include core subjects in Electrical Engineering, which can be taken in the junior year or as a sophomore if Unified Engineering is deferred to the junior year. The elective freedom can be utilized to take advanced subjects in guidance and control depending on the student's particular area of interest within the broad field of avionics.

Bachelor of Science in Aeronautics and Astronautics
Course XVI Program 2 Aeronautical and Astronautical Engineering: Avionics Option

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements		17 Subjects
Science Requirement		5
Humanities, Arts, and Social Sciences Requirement		8
Science Distribution Requirement [only two of these three subjects can be satisfied from among 6.071, 8.03, 18.03, and 16.001 in the Departmental Program]		3
Laboratory Requirement [can be satisfied by 6.111 or 16.622 in the Departmental Program]		1
	TOTAL Subjects	17

PLUS

Departmental Program		Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Basic Required Subjects		99
6.002	Circuits and Electronics, 15; 8.02**, *18.03***	
6.111	Introductory Digital Systems Laboratory, 12; 6.002**	
8.03	Physics III, 12; 8.02**, 18.02	
16.001	Unified Engineering I, 12; 8.01, *18.03*	
16.002	Unified Engineering II, 12; 8.01, *18.03*	
16.003	Unified Engineering III, 12; 16.001, 16.002	
16.004	Unified Engineering IV, 12; 16.001, 16.002	
18.03	Differential Equations, 12; 18.02**	
Advanced Required Subjects:		87 to 93
Two of the following seven subjects:		
6.001	Structure and Interpretation of Computer Programs, 15	
6.003	Signals and Systems, 15; 6.001, 6.002	
6.012	Electronic Devices and Circuits, 12; 6.002, 8.02	
6.013	Electromagnetic Fields and Energy, 12; 6.002, 8.02	
6.014	Electrodynamics 12; 6.013	
6.301	Solid State Circuits, 12; 6.012	
16.61	Microcomputer Laboratory, 12; 2.10, 6.002**	
One of the following three subjects:		
16.02	Aerodynamics, 12; 16.004**	
16.06	Molecular Gas Dynamics of Space and Re-entry, 12; 16.004**	
16.20	Structural Mechanics, 12; 16.004**	
One of the following two subjects:		
6.302	Feedback Systems, 12; 6.003**	
16.30	Principles of Automatic Control, 12; 18.03 *plus*	
16.40	Principles of Flight Guidance, 12; 16.30**	
16.621	Experimental Projects I, 3; 16.004	
16.622	Experimental Projects II, 12; 16.621	
One of the following two subjects:		
16.84	Flight Vehicle Engineering, 12; 16.02**	
16.85	Space Systems Engineering, 12; 16.20	
Units in Departmental Program that also satisfy the General Institute Requirements		(36 or 39)
Unrestricted Electives		48
Total Units Required for the S.B. Degree beyond the General Institute Requirements		198

Cooperative Program Course XVI-B

The cooperative program in Aeronautics and Astronautics provides undergraduates the opportunity to participate in professional activities in an aerospace organization for about seven months before their senior year. The program permits completion of requirements for the Bachelor of Science degree in four years. Students in this program become regular employees while working in the company, and are paid at prevailing rates.

Interested students should contact the professor in charge for details and an interview; also, students should arrange a schedule with their faculty advisor that permits an absence from MIT during either the first or the second term of the third year. One summer at MIT usually is necessary.

The curriculum requirements for this degree in Course XVI-B are the same as for Course XVI with the addition of required registration for 16.80 Industrial Practice during the plant work period, in place of eight units of elective.

Engineering Internship Program Course XVI-C

The Department of Aeronautics and Astronautics participates in the Engineering Internship Program (EIP) administered by the School of Engineering. It is intended as a five-year joint S.B.-S.M. program that features periods of work at a participating company, alternating with periods of study at MIT. See additional detailed discussion of this program in the introduction to the School of Engineering.

Interested students apply for participation in EIP during the spring term of their sophomore year. Once a selection is made and accepted, both the student and the company agree to continue that association to completion of the Program.

The student earns six units of credit for each of the two undergraduate work periods by registering for 16.801. The student also earns 12 units of graduate G credit through registration for 16.802 during the work period as a graduate student. The following spring and summer terms, he or she is usually required to be at MIT to complete the subject requirements and the thesis report. The Bachelor of Science and Master of Science degrees are then awarded simultaneously.

The work experiences provided under Course XVI-C are the same as for Course XVI with 16.801 (twice) used as 12 units of elective. For further information, please see the Department EIP Coordinator.

Double-Degree Program

Students may pursue two S.B. degrees under the Double-Degree Program outlined in Chapter III. In particular, some students may wish to combine a professional education in Aeronautics and Astronautics with a liberal education that links the development and practice of science and engineering with their social, economic, historical, and cultural contexts. For them, the Department of Aeronautics and Astronautics and the Department of Humanities (in cooperation with the Program in Science, Technology, and Society) offer a double-degree program that combines majors in Course XVI and Course XXI. A detailed description of that integrated degree program will be found under the description of the Program in Science, Technology, and Society.

Inquiries

For additional information concerning academic and research programs in the Department, admissions, suggested four-year undergraduate programs, interdisciplinary programs, financial aid, etc., please write to the Department of Aeronautics and Astronautics Undergraduate Office, Professor Winston R. Markey, Room 33-208, MIT, Cambridge, Massachusetts 02139, (617) 253-2279.

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Graduate Study

Bachelor of Science in Aeronautics and Astronautics
Course XVI
Program 1 Aeronautical and Astronautical Engineering

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 8.03, 18.03, and 16.001 in the Departmental Program.	
Laboratory Requirement can be satisfied by 16.622 in the Departmental Program.	

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Basic Required Subjects:		**96**
3.094	Materials Technology, 12	
6.071	Introduction to Electronics, 12; 18.01, *8.02*	
8.03	Physics III, 12; 8.02*, 18.02	
16.001	Unified Engineering I, 12; 8.01, *18.03*	
16.002	Unified Engineering II, 12; 8.01, *18.03*	
16.003	Unified Engineering III, 12; 16.001, 16.002	
16.004	Unified Engineering IV, 12; 16.001, 16.002	
18.03	Differential Equations, 12; 18.02*	
Advanced Required Subjects:		**75**
One of the following two subjects:		
16.02	Aerodynamics, 12; 16.004*	
16.06	Molecular Gas Dynamics of Space and Re-entry, 12; 16.004*	
	plus	
16.20	Structural Mechanics, 12; 16.004*	
16.30	Principles of Automatic Control, 12; 18.03	
One of the following two subjects:		
16.53	Rocket Propulsion, 12; 16.004	
16.54	Aircraft Engines and Gas Turbines, 12; 16.004	
	plus	
16.621	Experimental Projects I, 3; 16.004	
16.622	Experimental Projects II, 12; 16.621	
One of the following two subjects:		
16.84	Flight Vehicle Engineering, 12; 16.02*	
16.85	Space Systems Engineering, 12; 16.20	
Unrestricted Electives		**60**
Total Units Required for the S.B. Degree		**363**

*Alternate prerequisites are listed in the subject description.

Bachelor of Science in Aeronautics and Astronautics
Course XVI
Program 2 Aeronautical and Astronautical Engineering: Avionics Option

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 6.002, 8.03, and 16.001 in the Departmental Program.	
Laboratory Requirement can be satisfied by either 6.111 or 16.622 in the Departmental Program.	

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Basic Required Subjects:		**99 or 102**
6.002	Circuits and Electronics, 15; 8.02*, *18.03**	
One of the following two subjects:		
6.012	Electronic Devices and Circuits, 12; 6.002, 8.02	
6.003	Signals and Systems, 15; 6.001, 6.002	
	plus	
8.03	Physics III, 12; 8.02*, 18.02	
16.001	Unified Engineering I, 12; 8.01, *18.03*	
16.002	Unified Engineering II, 12; 8.01, *18.03*	
16.003	Unified Engineering III, 12; 16.001, 16.002	
16.004	Unified Engineering IV, 12; 16.001, 16.002	
18.03	Differential Equations, 12; 18.02	
Advanced Required Subjects:		**87**
6.111	Introductory Digital Systems Laboratory, 12; 6.002*	
One of the following two subjects:		
6.301	Solid State Circuits, 12; 6.012	
16.61	Microcomputer Laboratory, 12; 6.002*, 2.10	
One of the following three subjects:		
16.02	Aerodynamics, 12; 16.004*	
16.06	Molecular Gas Dynamics of Space and Re-entry, 12; 16.004*	
16.20	Structural Mechanics, 12; 16.004*	
One of the following two subjects:		
6.302	Feedback Systems, 12; 6.003*	
16.30	Principles of Automatic Control, 12; 18.03	
	plus	
16.40	Principles of Flight Guidance, 12; 16.30*	
16.621	Experimental Projects I, 3; 16.004	
16.622	Experimental Projects II, 12; 16.621	
One of the following two subjects:		
16.84	Flight Vehicle Engineering, 12; 16.02*	
16.85	Space Systems Engineering, 12; 16.20	
Unrestricted Electives		**60**
Total Units Required for the S.B. Degree		**378 or 381**

*Alternate prerequisites are listed in the subject description.

Graduate study in the Department of Aeronautics and Astronautics includes research work culminating in a thesis and study of graduate-level subjects in the Department and other departments and Schools at MIT. Degrees are awarded at the Master's, Engineer's, and Doctoral levels. The range of subject matter available is best conveyed by brief descriptions of the activities of the departmental divisions of instruction and the departmental laboratories. More detailed information may be obtained from the Graduate Office or from individual faculty members.

Divisions of Instruction and Research Laboratories

The graduate subject offerings of the Department are informally organized into six divisions: Mechanics and Physics of Fluids; Structures, Materials, and Aeroelasticity; Instrumentation, Guidance, and Control; Propulsion and Energy Conversion; Biomedical Engineering; and Aeronautical and Astronautical Systems. Research is conducted in a number of research laboratories. A faculty member is typically involved in teaching graduate and undergraduate subjects in one or more of the divisions, and in conducting research in one or more of the departmental laboratories or at the Charles Stark Draper Laboratory.

Mechanics and Physics of Fluids. Fluid mechanics is an essential discipline for diverse fields of engineering that are concerned with material, energy, and information transfer and their consequences. The principles of fluid mechanics are essential for an understanding of all flight regimes covering a wide range of speeds, altitudes, and fluid properties, from those associated with low-speed flight transportation to high-speed near-space operations, and space travel.

Research in fluid mechanics is carried on in several departmental laboratories. The focus of the Computational Fluid Dynamics Laboratory is on the development of improved algorithms and their application to external and internal flow fields for all speed ranges. Emphasis in the Fluid Dynamics Laboratory is on turbulence structure and flow stability. The Molecular Beam Laboratory employs techniques which examine the nature of interactions between the environment and vehicle surfaces. The Center for Aerodynamic Studies is concerned with the complex viscous flow about complete flight vehicles. Several laboratories operate wind tunnels. The Wright Brothers Facility is used for airfoil and nacelle research, rotor wing dynamics, aircraft development, and the simulation of wind loads on ground structures. An acoustic tunnel is equipped with an anechoic chamber for noise

research on conventional and VTOL aircraft. A low-turbulence tunnel provides test channels particularly suited for transition and turbulence investigations as well as airfoil study. In addition, several small open circuits are available for fluid mechanics research and configuration tests. All laboratories have access to several interactive computation systems and to experimental equipment serving their purposes.

Structures, Materials, and Aeroelasticity. The manifest importance of minimizing the structural weight fractions of aircraft and spacecraft has motivated the aerospace engineer to create new structural forms, to develop and exploit new materials such as the filamentary composites, to invent new analytical and numerical techniques for stress analysis, and to pursue aggressively a better understanding of catastrophic failures and longevity. These advances have stimulated many non-aerospace areas of design.

Research activities for students interested in Structures, Materials, and Aeroelasticity are centered primarily in the Technology Laboratory for Advanced Composites, the Space Systems Laboratory, and the Gas Turbine Laboratory. Facilities include vibration equipment, two computer-controlled universal testing machines, an autoclave for the fabrication of filamentary composite structural components, a blast chamber that can contain catastrophic failures, a large and a small chamber for the simulation of zero-g structural behavior, wind tunnels, and a blowdown compressor facility for the study of turbine engine aeroelasticity. Research is being conducted on the structural technology for high-performance aircraft, commercial transports, general aviation aircraft, and satellites. Other programs are directed toward the structural integrity of jet engines, the propeller blades of the advanced turboprop, and large space structures such as for a manned space station. All of the research requires the development of new experimental techniques as well as the concurrent development of design methodologies utilizing analytical as well as finite element methods.

Instrumentation, Guidance, and Control. Faculty members in this Division teach and perform theoretical and experimental research in control and its applications, navigation systems, instrumentation, estimation, lasers, digital systems, and other related topics.

One focus for the activities of the Instrumentation, Guidance, and Control Division is the Draper Laboratory, which offers opportunities for participation to students of US citizenship. Many Department faculty and students are actively involved in research programs in this Laboratory on guidance systems and components for all types of flight vehicles, including inertial guidance, using the advanced facilities for research on all phases of control and guidance. In the past this work has resulted in the development of many flight vehicle systems including the Apollo spacecraft navigation and guidance systems. Further detail on the Draper Laboratory is given in Chapter VI.

The Laser Systems Laboratory pioneers in the development and application of laser technology. Specific activities include optical gyroscopes; optical frequency standards; ultra-high-resolution spectroscopy and interaction of intense radiation with atoms and molecules.

Other control-related research projects are carried out in the Space Systems Laboratory and elsewhere in the Department, with substantial focus on the control of large flexible assemblies in space.

Biomedical Engineering. The Man-Vehicle Laboratory applies control and instrumentation disciplines to biological and psychological problems at the man-machine interface. It has been selected to perform manned space experiments on Spacelab-1 to investigate balance, adaptation to zero-g, and "space motion sickness." In addition, it conducts flight simulator studies on man in the loop, vehicle display and control, and air traffic control research. The laboratory also works on bioinstrumentation, physiological control systems, and clinical applications of the aerospace sciences. Activities include modeling of the human visual and vestibular system, flight simulation, cognitive learning, and work on diagnostic instrumentation for diseases of the eye and ear.

Propulsion and Energy Conversion. This division addresses, in teaching and research, those disciplines and technologies of special importance to propulsion and energy conversion. Subjects are offered in aircraft and rocket propulsion, and in advanced energy conversion. The Gas Turbine Laboratory provides unique experimental and computational facilities for research on fluid mechanics, heat transfer, and aeroelasticity in turbomachinery, and for research on space propulsion and power systems. Activities include theoretical and experimental study of transonic compressors and stability of compression systems, computational and experimental study of internal and external heat transfer in turbine blading, advanced engine controls, aeroelasticity of rotors, electric propulsion devices, and MHD power generation. The Laboratory has unique experimental facilities for the study of turbomachinery in the blowdown compressor, blowdown turbine, and internal cooling experiments.

Aeronautical and Astronautical Systems. The high levels of expenditure involved in the development of aeronautical and astronautical systems, their complexity and dependence on a variety of disciplines, and the high degree of interaction among these disciplines have all required the development of some method for integrating the total system and the development of formal analytical tools to optimize it as a whole rather than by parts. From this need has grown the concept of systems engineering, where successful application to the space program and to the analysis of transportation systems has amply demonstrated its effectiveness as an engineering tool.

The broad coverage of systems engineering clearly implies that the responsibilities of the engineer include far more than the design synthesis and construction of devices and facilities. The engineer must be aware of the social implications of his or her work and design, not only for maximum efficiency and safety, but also for minimum disruption of the environment.

Students interested in working in aeronautical and astronautical systems should place primary emphasis on a broad educational base that should include subjects in most of the divisions described earlier. In addition, the student should obtain training in the disciplines that support systems analysis, such as probability and statistics, operations research, economics, and computer science, and should also maintain an awareness of the external disciplines that help shape society, such as economics, law, and the social sciences. Most of this material would be obtained in the graduate program, and undergraduate students can become prepared for a more effective graduate program by a judicious choice of undergraduate elective subjects.

The research of the Systems Division is conducted in the Flight Transportation, the Space Systems, and the VTOL Technology Laboratories. The Flight Transportation Laboratory conducts research in many areas of flight transportation covering airline operations, air traffic control operations, aircraft navigation and guidance, airport planning, and the application of advanced operations research techniques to transportation systems. The Space Systems Laboratory analyzes concepts for space utilization and exploration, including space manufacturing, the design of large space structures, and space transportation.

Entrance Requirements for Graduate Study

In addition to the general requirements for admission to the Graduate School, applicants must have a strong undergraduate background in some of the fundamentals of aerospace engineering and mathematics as described in Undergraduate Study. Two terms of advanced mathematics beyond 18.03 Differential Equations or its equivalent are required either prior to, or as part of, all graduate programs. Gaps in preparation can be filled early in the graduate program.

New graduate students are normally admitted as candidates for the degree of Master of Science. Admission requirements for candidates for the Engineer in Aeronautics and Astronautics are more rigorous and such admission is ordinarily considered only after the candidate has spent some time in residence at MIT.

Admission to the Doctoral program is offered to students who have been accepted for graduate study and have passed the Doctoral Qualifying Examination. The Qualifying Examination seeks to measure the candidate's aptitude for engineering research, and understanding of the fundamental principles underlying aerospace engineering. This examination is offered once each year, usually during the January Independent Activities Period. Students who wish to be considered for the Doctoral Program must pass the Qualifying Examination before the fourth semester following initial registration in the graduate program. A prospective candidate may take this examination only once.

The Department of Aeronautics and Astronautics requires that all entering graduate students demonstrate satisfactory English writing ability by taking the Writing Diagnostic Examination offered by the Writing Program of the MIT Humanities Department. The examination is usually administered during the week after the initial date of registration in Graduate School, and all entering candidates must take the examination at that time. Those whose skills are found deficient will be required to complete remedial training specifically designed to fulfill their individual needs.

In addition, foreign candidates whose language of instruction has not been English for at least five years, must take the MIT English Evaluation Test for Foreign Graduate Students after registration. The examination is held in early September and late January. On the basis of performance on this examination, the faculty may prescribe remedial courses in English offered at MIT.

Master of Science in Aeronautics and Astronautics

The general requirements for the Master of Science degree are cited in Chapter IV. The specific Departmental requirements are an acceptable thesis, and at least 66 subject units, typically in graduate subjects relevant to the candidate's area of technical interests. Of the 66 units, 42 units must be in "A" level subjects, of which at least 21 units must be in Departmental subjects. To be credited toward the degree, non "A" level subjects must carry a grade of B or better. Full-time students normally must be in residence one full academic year. Students holding Research Assistantships will require a longer period of residence.

The Department requires two terms of advanced mathematics beyond 18.03 Differential Equations, one of which must be either 18.075 or 18.085 or their equivalents. This requirement may be fulfilled either prior to or as a part of the Master's program. The choice of subjects in the area of major interest and the thesis topic are arranged individually by each student in consultation with a faculty advisor; the program of study must have the approval of the faculty advisor, who acts in behalf of the Department faculty.

Master of Science in Technology and Policy

Students interested in applying their aeronautical engineering background to problems of policy and socioeconomic assessment of technology may apply for the interdepartmental Master of Science Program in Technology and Policy. This program combines subjects in advanced technology with subjects in economics, systems analysis, political science, and law and engages the student in significant project work integrating technology and policy. General requirements and application procedures are described in Chapter VI.

Master of Science in the Management of Technology

Individuals who would like to apply their Aeronautics/Astronautics engineering background and at least five years of technical work experience to issues in technical management may want to explore the Program in the Management of Technology. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, this program entails a rigorous twelve-month curriculum, focusing on management principles for technical people in a technical environment. The program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program and application procedures are described in Chapter VI.

Engineer in Aeronautics and Astronautics

The Program leading to the degree of Engineer in Aeronautics and Astronautics is offered for students interested in a greater breadth of graduate subjects than is normally associated with a Master's or Doctoral program, and less emphasis on research than required of Doctoral candidates. The minimum study program of 162 subject units must include graduate subjects from each of the divisions of instruction, and the thesis work must have a strong engineering, as distinct from a scientific, orientation. Two years beyond the Bachelor of Science degree normally are required for completion of this degree by a full-time student.

Doctor of Philosophy and Doctor of Science

The general requirements for this degree are given in Chapter IV. To be considered for the Doctoral program, a candidate must pass the Doctoral Qualifying Examination. Other requirements for admission to the program and for the program itself are outlined in a booklet entitled *The Doctoral Program.* Briefly, after selecting an area for study and research, the candidate in consultation with the thesis supervisor forms a doctoral thesis committee, which assists in the formulation of the individual's research and study programs and monitors the student's progress. The subjects selected to fulfill the major and minor program requirements must be approved by the committee. One foreign language is required and also must be approved by the student's committee. The candidate's mastery of the major and minor areas is tested by a written and an oral General Examination administered by the doctoral thesis committee after completion of the major and minor subjects.

Demonstrated competence for original research at the forefront of aerospace engineering is the final and major criterion for granting the Doctoral degree. The candidate's thesis serves in part to demonstrate such competence, and on completion is defended orally in a presentation to the faculty of the Department, which may then recommend the award of the degree.

Interdisciplinary Programs

The graduate division of the Department participates in several interdisciplinary fields, which are of special importance for Aeronautics and Astronautics in both research and the curriculum.

Biomedical Engineering. This program is available to students interested in biomedical instrumentation and physiological control systems where the disciplines involved in Aeronautics and Astronautics are applied to biology and medicine. Graduate study based on this program may be pursued within the Departmental program, the MIT Division of Health Sciences and Technology S.M.-Ph.D. Program in Medical Engineering and Medical Physics, or the Interdepartmental Ph.D. program in Biomedical Engineering. At the Master's degree level, students in the Department may specialize in biomedical engineering, emphasizing quantitative physiology, instrumentation and control, and biostatistics, or in man-machine systems and engineering psychology and in instrumentation and statistics. For a further description of these programs, please see Chapter VI under Biomedical Engineering. Most biomedical engineering research in the Department of Aeronautics and Astronautics is conducted in the Man-Vehicle Laboratory.

Flight Transportation. For students interested in a career in flight transportation, there is available a program that incorporates a broader graduate education in disciplines such as economics, management, law, and operations research than is normally pursued by candidates for degrees in Engineering. Graduate research emphasizes one of the five areas of flight transportation: Flight Vehicle Design and Control; Airport Planning and Design; Air Traffic Control; Air Transportation Systems Analysis; and Airline Economics and Management, with subjects selected appropriately from those available in the Departments of Aeronautics and Astronautics, Civil Engineering, Economics, and the Center for Transportation Studies. A special interdepartmental program may be established for the doctoral student (or participation in the Operations Research Center Program may be considered, see Chapter VI).

Fellowships, Research and Teaching Assistantships

Financial assistance for graduate study may be in the form of fellowships or research or teaching assistantships. There are several endowed and departmental fellowships that are granted to students of exceptional promise. The Department attempts to place a student in a laboratory in which the research activity is closely related to the student's interests. Both the fellowship student and the research assistant work with a faculty supervisor on a specific research assignment of interest, which generally leads to a thesis.

Inquiries

For additional information concerning academic and research programs in the Department, admissions, interdisciplinary programs, financial aid, assistantships, etc., please contact the Department of Aeronautics and Astronautics Graduate Office, Professor H. Y. Wachman, Room 33-208, MIT, Cambridge, Massachusetts 02139, (617) 253-2260.

Department of Chemical Engineering

(Course 10)

James Wei, Sc.D.
Warren K. Lewis Professor of Chemical Engineering
Head of the Department

Robert Arthur Brown, Ph.D.
Arthur Dehon Little Professor of Chemical Engineering
Executive Officer of the Department

Professors

Robert Calvin Armstrong, Ph.D.
Professor of Chemical Engineering
Graduate Officer

Raymond Frederick Baddour, Sc.D.
Lammot du Pont Professor of Chemical Engineering

Jénos Miklós Beér, Sc.D.
Professor of Chemical and Fuel Engineering

Howard Brenner, Sc.D.
Willard Henry Dow Professor of Chemical Engineering
(On leave)

Robert Edward Cohen, Ph.D.
Bayer Professor of Chemical Engineering

Clark Kenneth Colton, Ph.D.
Professor of Chemical Engineering

Charles Leland Cooney, Ph.D.
Professor of Chemical and Biochemical Engineering

William Murray Deen, Ph.D.
Professor of Chemical Engineering

Lawrence Boyd Evans, Ph.D.
Professor of Chemical Engineering

Jack Benny Howard, Ph.D.
Professor of Chemical Engineering

Marcus Karel, Ph.D.
Professor of Chemical and Food Engineering

Robert Samuel Langer, Sc.D.
Professor of Chemical and Biochemical Engineering

Edward Wilson Merrill, Sc.D.
Carbon P. Dubbs Professor of Chemical Engineering

Adel Fares Sarofim, Sc.D.
Professor of Chemical Engineering

Charles Nelson Satterfield, Sc.D.
Professor of Chemical Engineering

Kenneth Alan Smith, Sc.D.
Professor of Chemical Engineering
Associate Provost
Vice President for Research

George Stephanopoulos, Ph.D.
Joseph R. Mares Professor of Chemical Engineering

Gregory Stephanopoulos, Ph.D.
Professor of Chemical Engineering

Ulrich Werner Suter, Dr.Sc.Techn.
Professor of Chemical Engineering
(On leave)

Jefferson William Tester, Ph.D.
Professor of Chemical Engineering
Director, School of Chemical Engineering Practice

Daniel I. C. Wang, Ph.D.
Chevron Professor of Chemical Engineering
Director, Biotechnology Process Engineering Center

Associate Professors

Trevor Alan Hatton, Ph.D.
Class of 1922 Associate Professsor of Chemical Engineering

Herbert Harold Sawin, Ph.D.
Associate Professor of Chemical Engineering

Preetinder Singh Virk, Sc.D.
Associate Professor of Chemical Engineering

Assistant Professors

Edmundo Daniel Blankschtein, Ph.D.
Texaco-Mangelsdorf Assistant Professor of Chemical Engineering

Jeffrey Lee Feerer, Ph.D.
Assistant Professor of Chemical Engineering
Station Director, School of Chemical Engineering Practice

Karen Klincewicz Gleason, Ph.D.
Herman P. Meissner 1929 Assistant Professor of Chemical Engineering

Mark Albert Kramer, Ph.D.
Assistant Professor of Chemical Engineering

Gregory John Mehos, Ph.D.
Assistant Professor of Chemical Engineering
Station Director, School of Chemical Engineering Practice

Visiting Professor

Jean Paul Leinroth, Jr. Sc.D.
Professor of Chemical Engineering
Station Director, School of Chemical Engineering Practice

Administrative Officer

Robert Choate Morrow, B.S.

Senior Lecturer

Charles Michael Mohr, Sc.D.
Undergraduate Officer

Lecturers

John Roos Ehrenfeld, Sc.D.
Colin Robert Gardner, Ph.D.
(Visiting)
David John Goldstein, Sc.D.
Peter McAllum Walsh, Ph.D.

Instructor

Harry Ward Fine, M.S.
Assistant Station Director, School of Chemical Engineering Practice

Senior Research Associate

Charles V. Berney, Ph.D.

Principal Research Associate

Maria Flytzani-Stephanopoulos, Ph.D.

Research Associate

Zahra Nakhost, M.S.

Postdoctoral Associates

Steven Roy Burdette, Ph.D.
Thomas Chattaway, Ph.D.
Linda G. Cima, Ph.D.
Smadar Cohen, Ph.D.
Deborah Leckband, Ph.D.
William Robert Licht, Ph.D.
Jean-Philippe Nicolai, Ph.D.
Eyal Ron, Ph.D.
Norman F. Sheppard, Jr., Ph.D.
Hyun Hoon Song, Ph.D.

Postdoctoral Fellows

Gabriela Patricia Henning, Ph.D.
Horacio Pascual Leone, Ph.D.

Graduate Student Administrator

Jean Anne Bueche, B.A.

Technical Instructor

Stanley Robert Mitchell

Visiting Scientists

Naoru Hamaguchi, Ph.D.
Edward S. Josephson, Ph.D
Peter Luthi, Ph.D.
Pavle P. Matijasevic, M.S.
Masaru Matsuzaki, B.S.
Ramnath Sasisekharan, M.S.
Martin Leon Yarmush, M.D., Ph.D.

Research Affiliates

Larry Richard Brown, Sc.D.
Hugh D. Conlon, Ph.D.
Laurent Dubois, M.S.
Elazer R. Edelman, Ph.D.
Kirshenendu Ghosh, Ph.D.
Stephen Haralampu, Ph.D.
Paul Gerhard Kibat, Ph.D.
Michael Klagsbrun, Ph.D.
Edith Mathiowitz, Ph.D.
Claudy Mullon, D.Sc.
Barry Alan Solomon, Ph.D.
Michael Bernard Stemerman, M.D.
Warren Myron Zapol, M.D.

Professors Emeriti

Hoyt Clarke Hottel, A.B., S.M.
Professor of Chemical Engineering, Emeritus

John Ploeger Longwell, Sc.D.
Professor of Chemical Engineering, Emeritus
Senior Lecturer

Herman Paul Meissner, D.Sc.
Professor of Chemical Engineering, Emeritus

Robert Clark Reid, Sc.D.
Professor of Chemical Engineering, Emeritus

Johnson Edward Vivian, Sc.D.
Professor of Chemical Engineering, Emeritus

Glenn Carber Williams, Sc.D.
Professor of Chemical Engineering, Emeritus

Department of Chemical Engineering

(Course 10)

Undergraduate Study

Chemical engineering is a broadly based discipline, having a deep involvement with chemistry along with the applications of physics and mathematics, which are common to all engineering disciplines. In its broadest sense, chemical engineering is the creative application of chemistry to the solution of significant problems. Chemical engineering is making substantial contributions to the development of clean energy sources, to the provision of adequate food supplies, to the recreation of proper ecological balances, to the advancement of medical/ engineering science, and to the economic production of material goods.

The Department of Chemical Engineering at MIT offers two **undergraduate programs.** One is Course X, leading to the Bachelor of Science in Chemical Engineering. This program is accredited by the Accreditation Board for Engineering and Technology and the American Institute of Chemical Engineers. The other program is Course X-C, leading to the Bachelor of Science without specification, which is not accredited and requires less study in formal chemical engineering subjects.

The Department offers a wide selection of **graduate** subjects and research leading to advanced degrees in chemical engineering. Important subject areas include fuels and energy, polymer chemistry, surface and colloid chemistry, biomedical engineering, biochemical engineering, chemical process development, transport processes, and environmental engineering. Many of our current undergraduates find it attractive in the upperclass years to take a variety of these graduate-level subjects. This exposure is invaluable in identifying potential independent research interests for the student. Other students find these subjects to be fruitful as terminal technical subjects prior to moving on to work in engineering, government, or management. Students interested in the various areas of graduate study in Chemical Engineering should consult the section on Graduate Study.

The School of Chemical Engineering Practice, also described in detail in the graduate section, involves one term of work under the direction of an Institute staff resident at the Practice School Stations. There each student has a unique opportunity to develop the ability to apply basic professional principles to the solution of practical problems in industry.

The undergraduate curriculum in chemical engineering provides basic studies in physics and mathematics, a major concentration in chemistry, and a strong core of chemical engineering. The four-year undergraduate programs, designed to develop judgment, initiative, and responsibility, give students considerable latitude in arranging a selection of subjects that best fits their needs. Those who expect to go on to graduate school may therefore elect subjects that strengthen their preparation for advanced work.

In addition to work in science and engineering, students take an integrated sequence of subjects in the humanities and social sciences. The chemical engineer's progress and accomplishments are not determined solely by technological competence; fully as important are a breadth of outlook and an understanding of society. The curriculum provides a sound preparation for going on to jobs in industry or government, and for graduate work.

Chemical engineering also provides an ideal preparation for careers in medicine and related fields of health science and technology. The Department's strong emphasis on chemistry provides excellent training toward medical school. A suitable program of study may be arranged within the regular curricula of Course X or X-C. Interested students should consult with their faculty advisor.

A departmental brochure gives typical four-year programs and provides advice in choosing electives in chemistry and chemical engineering. Undergraduates are encouraged to take part in the research activities of the Department.

Bachelor of Science in Chemical Engineering Course X

The student who decides early to major in chemical engineering is encouraged to begin taking professional subjects. For example, 5.11 Principles of Chemical Science, 5.12 Organic Chemistry I, and 10.001 Introduction to Computer Methods may be taken in the freshman year. If the subjects 10.13, 10.14, 18.03, and 10.301 are taken in the sophomore year, the student is in an excellent position for professional work in some depth in the third and fourth years.

Some students may wish to defer choice of a major field or exercise maximum freedom during the first two years. If the Science Distribution Subjects chosen in the second year include 18.03 and two are in the field of fluid mechanics, thermodynamics, chemistry, biology, or chemical engineering, students can generally complete the requirements for a degree in chemical engineering in two more years. Students are advised to discuss their proposed program with a Course X faculty advisor as soon as they become interested in a degree in chemical engineering.

Bachelor of Science in Chemical Engineering Course X

Degree requirements applicable to the Class entering MIT in September 1987 (Class of 1991) and subsequent Classes (For degree requirements applicable to classes entering MIT prior to 1987, please see text immediately following this chart.):

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [two subjects can be satisfied by 10.13 and 18.03 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 5.310 or 5.311 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program		**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		156
One of the following two subjects:		
5.310	Laboratory Chemistry, 12; 5.12	
5.311	Introductory Chemical Experimentation, 12; 5.12	
	plus	
511	Principles of Chemical Science[1], 12	
5.12	Organic Chemistry I, 12; 5.11	
	plus	
10.001	Introduction to Computer Methods[2], 6	
	plus	
10.13	Chemical Engineering Thermodynamics I, 12; *18.02*	
10.14	Chemical Engineering Thermodynamics II, 9; 10.13	
	plus	
One of the following two subjects:		
10.26	Chemical Engineering Laboratory, 12; 5.11, 10.14, 10.302, 10.37	
10.27	Chemical Engineering Processes Laboratory, 12; 10.13, 10.14, 10.301	
	plus	
10.301	Fluid Mechanics, 12; 18.03	
10.302	Transport Processes, 12; 10.13, 10.301	
10.32	Separation Processes, 12; 10.14, 10.302	
10.361	Integrated Chemical Engineering I, 12; 10.32, 10.37	
10.362	Integrated Chemical Engineering II, 12; 10.361	
10.37	Chemical Kinetics and Reactor Design, 9; 10.13, 10.301	
18.03	Differential Equations, 12; 18.02*	

*Alternate prerequisites are listed in the subject description.

1
Students who use 5.11 to fulfill the General Institute Requirements in Chemistry/Biology must take 12 additional units of Unrestricted Elective.

2
Requirement can also be satisfied in the following ways: successful completion of IAP offering in Course 10; 1.00; 2.10; or passing a proficiency examination offered by the department.

Restricted Electives:	**21—27**

One subject in Chemical Engineering, except 10.UR, 10.91, 10.ThU, 10.10, 10.11 or 10.801—10.816; plus one laboratory subject from the following list:

3.081	Materials Laboratory, 15
5.32	Intermediate Chemical Experimentation, 15; 5.310 or 5.311, *5.13, 5.60*
7.011	Introduction to Experimental Biology, 15; 7.01 or 7.05
10.66J	Polymer Morphology and Properties Laboratory, 12
10.67	Polymer Science Laboratory, 12
10.26*	Chemical Engineering Laboratory, 12; 5.11, 10.14, 10.302, 10.37
10.27*	Chemical Engineering Processes Laboratory, 12; 10.13, 10.14 10.301
10.ThU	Undergraduate Thesis, 12

Units in Departmental Program that also satisfy the General Institute Requirements	**(36)**
Unrestricted Electives	**45—51**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**192**

For the degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990), please see last year's catalogue. The requirements are similar to those for Classes entering MIT in 1987 and subsequent classes; in place of 10.001, a student takes 10.01, and in place of 10.361 and 10.362, a student takes 10.36.

The degree requirements applicable to classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

Bachelor of Science Course X-C

Students in Course X-C are permitted to plan programs involving basic subjects in chemistry and chemical engineering, but instead of continuing in depth in these areas, can study in other fields, such as other engineering disciplines, biology, biomedical engineering, economics, or management. Course X-C has proven to be especially attractive to students who wish to specialize in chemistry, physics, biology, patent law, or management while simultaneously gaining a broad exposure to the engineering approach to solving problems.

Students planning to follow this curriculum should discuss their interests with a member of the faculty of the Department. At the time they decide to enter the Course X-C program, preferably by the first term of their senior year, they should submit to the Department a statement of goals and a program of subjects which achieves their objectives. Students are assigned a member of the Department faculty as an advisor.

Departmental requirements for Course X-C are 5.11, 10.13, 10.14, and 10.301, plus a coherent program of subjects (102 units) including at least 30 units in chemical engineering. Further details may be obtained from the Department.

Five-Year Programs/Joint Programs

In addition to offering separate programs leading to the Bachelor of Science and Master of Science in Chemical Engineering, the Department offers a program leading to the simultaneous award of both degrees at the end of five years. A detailed description of this program is available from the Graduate Registration Officer. Students in the five-year program normally enroll in the School of Chemical Engineering Practice.

For chemical engineering students interested in nuclear applications, the Department of Chemical Engineering and the Department of Nuclear Engineering offer a five-year program leading to the joint Bachelor of Science in Chemical Engineering and Master of Science in Nuclear Engineering. Such programs are approved on an individual basis between the registration officers of the two departments.

Inquiries

Additional information concerning undergraduate academic and research programs, admissions, and financial aid may be obtained by writing to Dr. C. M. Mohr, Undergraduate Officer, Department of Chemical Engineering, Room 66-405, MIT, Cambridge, Massachusetts 02139, (617) 253-2015.

*Either 10.26 or 10.27 must be taken as a Departmental Requirement and cannot also be used to satisfy this Restricted Laboratory Requirement.

Bachelor of Science in Chemical Engineering Course X

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	**Total Units**
Science Requirement	**60**
Humanities, Arts, and Social Sciences Requirement	**72**
Science Distribution Requirement can be satisfied by 10.13, 18.03, and 5.11 in the Departmental Program.	
Laboratory Requirement can be satisfied by 5.310 or 5.311 in the Departmental Program.	

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects:		**150**
One of the following two subjects:		
5.310	Laboratory Chemistry, 12; 5.12	
5.311	Introductory Chemical Experimentation, 12; 5.12	
	plus	
5.11	Principles of Chemical Science[1], 12	
5.12	Organic Chemistry I, 12; 5.11	
	plus	
One of the following three subjects:		
5.13	Organic Chemistry II, 12; 5.12	
5.62	Physical Chemistry, 12; 10.13[2]	
7.05	General Biochemistry, 12; 5.12	
	plus	
10.01	Engineering Concepts and Computer Methods, 12	
10.13	Chemical Engineering Thermodynamics I, 12; *18.02*	
10.14	Chemical Engineering Thermodynamics II, 9; 10.13	
	plus	
One of the following two subjects:		
10.26	Chemical Engineering Laboratory, 12; 5.11, 10.14, 10.302, 10.37	
10.27	Chemical Engineering Processes Laboratory, 12; 10.13, 10.14, 10.301	
	plus	
10.301	Fluid Mechanics, 9; 18.03	
10.302	Transport Processes, 9; 10.13, 10.301	
10.32	Separation Processes, 9; 10.14, 10.302	
10.36	Process Design, 9; 10.302, 10.32	
10.37	Chemical Kinetics and Reactor Design, 9; 10.13, 10.301	
18.03	Differential Equations, 12; 18.02[2]	

1
Students who use 5.11 to fulfill the General Institute Requirements in Chemistry must take 12 additional units of Unrestricted Elective.
2
Alternate prerequisites are listed in the subject description.

Restricted Electives:		**at least 18**
One subject in Chemical Engineering, except 10.UR, 10.91, 10.ThU, 10.10, 10.11 or 10.801—10.816; plus one laboratory subject from the following list:		
3.081	Materials Laboratory, 15	
5.32	Intermediate Chemical Experimentation, 15; 5.310 or 5.311, *5.13, 5.60*	
7.011	Introduction to Experimental Biology, 15; 7.01 or 7.05	
10.66J	Polymer Morphology and Properties Laboratory, 12	
10.67	Polymer Science Laboratory, 12	
10.26*	Chemical Engineering Laboratory, 12; 5.11, 10.14, 10.302, 10.37	
10.27*	Chemical Engineering Processes Laboratory, 12; 10.13, 10.14, 10.301	
10.ThU	Undergraduate Thesis, 12	
20.002	Laboratory in Applied Biology[1], 15	
Unrestricted Electives		**66**
Total Units Required for the S.B. Degree		**366**

*Either 10.26 or 10.27 must be taken as a Departmental Requirement and cannot also be used to satisfy this Restricted Laboratory Requirement.
[1]This subject is no longer offered beginning 1988-89.

Graduate Study

Fields of Graduate Study

The technology of chemical engineering in the process industries falls loosely into two categories: physical and chemical. While both types are encountered in many industrial problems, graduate subjects of instruction and research are logically grouped in the corresponding fields of engineering operations and applied chemistry. Most graduate students take some work in each field, and in the School of Chemical Engineering Practice the problem assignments involve fundamentals in both areas. Specific subjects in each of the following fields of applied chemistry and engineering operations are described in Chapter VIII.

Applied Chemistry. The Department offers a diversified program in applied chemistry, designed for students who wish to broaden their competence in the chemical aspects of chemical engineering. This program provides subjects in industrial chemistry and chemical thermodynamics; chemical kinetics and reactor engineering, with emphasis on heterogeneous and catalytic processes; and the physical chemistry of ion exchange, adsorption, and chromatography. The subjects listed under Fuel and Fossil Energy Engineering and Materials Science and Engineering also include applied chemistry. Much of the Department's research activity falls into these areas, and unique laboratory facilities are provided.

A well-rounded program in applied chemistry might also include subjects given by other departments in advanced organic, inorganic, or physical chemistry; biochemistry, enzymology, or bacteriology; and physical metallurgy, electrochemistry, corrosion, or ceramics.

Biochemical Engineering. Recent achievements in molecular biology have greatly stimulated interest in biotechnology and offer exciting opportunities to the chemical engineer. Biotechnology is the integration of biochemistry, microbiology, and chemical engineering. Biochemical engineering is at the interface between biological sciences and engineering principles. Important problems in this field in which the Department has active research programs are biocatalysis, microbial kinetics, transport phenomena in biological and particularly microbial systems, bioseparations, bioreactor design, control of microbial reactions, enzyme technology, renewable resource utilization, and bioengineering of mammalian cell cultures. Students interested in biochemical engineering have the opportunity to participate in an active research program while taking coursework in a variety of relevant subjects offered by the Department. Subjects also are available in biochemistry, microbiology, enzymology and molecular biology, which are taught in other Departments (Biology and Chemistry).

Biomedical Engineering. The application of chemical engineering to problems in the life sciences and medicine has become an increasingly important area of research. The broad backgrounds of chemical engineers, spanning both fundamental and applied aspects of chemistry and physics, makes them uniquely qualified to handle such tasks. Students interested in this area have the opportunity to draw upon the Department's diverse offering of subjects in the chemical engineering sciences.

The Department's active graduate research program in biomedically related areas is characterized by an interdisciplinary approach to both fundamental and applied problems. Many projects involve collaboration with physicians, surgeons, and life scientists in other departments and in local hospitals associated with Harvard Medical School. Research topics include the rheology of non-Newtonian biological fluids; mass transfer in blood and in artificial organs, such as the artificial kidney and blood oxygenator; synthesis of blood-compatible synthetic biomaterials; membrane transport phenomena; synthetic replacement of the lung surfactant; physical properties of biopolymers; and ultrafiltration of solutions of biological macromolecules.

Reaction Engineering. Chemical reactor engineering is concerned with the science and technology of chemical reactions that take place in reactors, leading to the production of useful chemicals and materials. It involves the interaction between chemistry, fluid mechanics, and heat transfer, and also includes study of catalytic reactions. The heart of a chemical plant or refinery is a reactor, surrounded by pumps, heat exchangers, and separation equipment. Active research programs in many aspects of this field are being carried out, and a number of relevant courses is offered.

Process and Systems Engineering. The variety of graduate subject offerings provides opportunity for programs in process simulation, process control, heat transfer, fluid mechanics, and separations — subjects that are basic in process engineering. Opportunities for research of an advanced nature in these areas are available.

Programs also may include advanced subjects in mathematics, instrumentation, fluid mechanics, and metallurgy, plus subjects offered in other departments.

Fuel and Fossil Energy Engineering. The problem of supplying energy economically while meeting environmental constraints is growing in importance and complexity, thus providing opportunities for major research and engineering contributions in the fields of combustion and fuel conversion. Combustion involves all the basic chemical engineering skills and a knowledge of high-temperature chemistry and complex radiative heat transfer. Fuel conversion processes such as coal pyrolysis, gasification, and liquefaction involve the problems of the chemistry of complex mixtures with an important requirement for selective production of the desired products.

An integrated program in the field typically includes subjects in heat, momentum and mass transfer, thermodynamics, kinetics, combustion, radiation, and a research problem in combustion or fuel conversion. The Department's Fuels Research Laboratory provides excellent facilities for research on a wide range of problems. Through cooperative programs with the Energy Laboratory (described in Chapter VI), it also offers the opportunity to work in facilities of sufficient size to address many of the pressing problems of fluidized bed and conventional combustion of difficult fuels on a realistic scale. Control of pollutants in both fuel manufacture and combustion is a major thrust of the research program.

Polymers and Materials Engineering. The Department maintains an active and diversified graduate research program in surface chemistry, polymer chemistry, and polymer physics and offers a coordinated instructional program in these areas. Students whose interests lie in the direction of surface phenomena or polymeric materials thus have a rare opportunity to develop specialized skills in these areas in an atmosphere where the focus of attention is on the applied, as well as the basic, scientific aspects.

Graduate research activities in these fields include topics such as the rheology of bulk polymers, polymer solutions and particulate dispersions, molecular transport phenomena in polymers, structure and properties of elastomers and microcrystalline thermoplasts, permselective membranes, polymers in turbulent drag reduction and for medical application, selective transformation of polymer surfaces by chemical and high-energy radiation, and XPS studies of polymer surfaces in relation to bulk composition, polymer blends, and block copolymers. Collaboration between chemical engineering and many other departments in the supervision of these research projects brings an interdisciplinary approach to the entire program.

For students with strong interest in materials and an adequate background in chemistry or chemical engineering, the Department offers special graduate curricula leading to the degrees of Materials Engineer, Doctor of Science, or Doctor of Philosophy. These curricula are designed to provide a properly integrated background in the science and engineering of the major classes of materials (metals, ceramics, and polymers) and also to specialize in some depth in a selected area of the field. Specific graduate programs in this area are suggested by, and subject to the approval of, an interdepartmental committee on materials engineering. Further details may be obtained by consulting the Department's Graduate Registration Officer.

School of Chemical Engineering Practice

Since its inception in 1916 the School of Chemical Engineering Practice has been a major feature of the graduate education in the Department. In this unique program students receive intensive instruction to broaden their education, not only in the technical aspects of the profession, but also in communication skills and human relations, which are frequently decisive in the success of an engineering enterprise. The Practice School program stresses problem solving in an engineering internship format, where students undertake projects at industrial sites under the direct supervision of resident MIT faculty. Credit is granted for participation in Practice School in lieu of preparing a master's thesis.

The operation of the Practice School is quite similar to a small consulting company. The resident staff work closely with the technical personnel of the host companies in identifying project assignments with significant educational merit, and with solutions that make important contributions to the operation of the host plants.

At Practice School, students work on three or four different projects. Groups and designated group leaders change from one project to another, giving every individual an opportunity to be a group leader at least once.

Students in the Practice School Program are required to demonstrate proficiency in or take one graduate subject in each of the following areas: Thermodynamics, Heat and Mass Transfer, Applied Process Chemistry, Kinetics and Reactor Design, and Applied Mathematics.

Advanced Degrees

The following advanced degrees are offered in chemical engineering: the Master of Science in Chemical Engineering or the Master of Science in Chemical Engineering Practice; Chemical Engineer, Environmental Engineer, or Materials Engineer; Doctor of Science or Doctor of Philosophy. Preparation equivalent to 5.62 Physical Chemistry and 5.12 Organic Chemistry I is normally essential for any graduate work in chemical engineering. More detailed descriptions of each of the following programs can be obtained from the graduate registration officer in the Department.

Master of Science in Chemical Engineering. Programs for the Master of Science in Chemical Engineering usually are arranged as a continuation of undergraduate professional training, but at a greater level of depth and maturity. The general requirements for a Master's program are given in Chapter IV. To complete the requirements of at least 66 subject units, of which 42 units must be in "A" subjects, together with an acceptable thesis, generally takes one academic year.

Master of Science in Chemical Engineering Practice. The unit requirements for the Master of Science in Chemical Engineering Practice (Course X-A) are the same as those for the Master of Science in Chemical Engineering, except that 36 units of practice school experience may be accepted in lieu of the Master's thesis.

Bachelor of Science graduates of this Department can meet the requirements for the Master of Science in Chemical Engineering Practice (Course X-A) in two terms. Beginning in the September following graduation, students are at the field stations until the end of December, and then return to the Institute to complete the program during the spring term. A similar Practice School field program begins in February and extends to the end of May.

For students who have graduated in chemical engineering from other institutions, the usual program of study for the Master of Science in Chemical Engineering Practice involves two terms at the Institute followed by the field station work in the Practice School. Graduates in chemistry from other institutions normally require an additional term.

Master of Science in Technology and Policy. Students interested in applying their chemical engineering background to problems of policy and socioeconomic assessment of technology may apply for the interdepartmental Master of Science Program in Technology and Policy. This program combines subjects in

advanced technology in the particular field of the student's choosing with subjects in economics, systems analysis, political science, and law. General requirements and application procedures are described in Chapter VI.

Chemical Engineer. The Engineer's degree is offered for those students who desire an advanced graduate education in depth but who are not interested primarily in research. The program of study and research normally includes attendance at the Practice School, completion of an approved integrated minor consisting of at least 24 units outside the Department. A detailed description of the Chemical Engineer's program may be obtained from the Graduate Registration Office.

Materials Engineer. Candidates interested in studying materials engineering in the Department of Chemical Engineering should have training equivalent to that offered by the Institute in its undergraduate programs in chemistry or chemical engineering. In general, two years are required for completion of the Materials Engineer.

Master of Science in the Management of Technology

Individuals who would like to apply their chemical engineering background and at least five years of technical work experience to issues in technical management may want to explore the Program in the Management of Technology. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, this program entails a rigorous twelve-month curriculum, focusing on management principles for technical people in a technical environment. The program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program and application procedures are described in Chapter VI.

Doctor of Science or Doctor of Philosophy. Admission to the doctoral program is granted only after the candidate has passed a written and oral general examination. The examination is given in January and May. It is usually taken at the end of the second term in residence as a graduate student, although students with good preparation should attempt the exam after one term. It is not necessary to complete a Master's program in order to obtain a doctorate.

The requirements for the doctoral degree include a program of advanced study, a minor program, and a thesis. The program of advanced study and research is normally carried out in one of the fields of chemical engineering under the supervision of one or more faculty members in the Department of Chemical Engineering.

The joint program with the Woods Hole Oceanographic Institution is intended for students whose primary career objective is oceanographic engineering. The program is described in more detail under the section at the end of this chapter on MIT's Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution.

Financial Support

The Department has a wide variety of financial support for graduate students, including teaching and research assistantships, fellowships, and loans. Information about financial assistance may be obtained by writing to the Graduate Registration Officer, but consideration for awards cannot be given before the admissions decisions have been made.

Inquiries

Additional information concerning graduate programs, admissions, financial aid, assistantships, etc., may be obtained by writing to the Graduate Office, Department of Chemical Engineering, Room 66-366, MIT, Cambridge, Massachusetts 02139, (617) 253-4579.

Department of Civil Engineering

David Hunter Marks, Ph.D.
Professor of Civil Engineering
Head of the Department

Professors

Gregory Bert Baecher, Ph.D.
Professor of Civil Engineering
(On leave)

Mohsen Mohamed Baligh, Ph.D.
Professor of Civil Engineering

Moshe Emanuel Ben-Akiva, Ph.D.
Professor of Civil Engineering
(On leave)

Rafael Luis Bras, Sc.D.
Professor of Civil Engineering
Director, Parsons Laboratory

Oral Buyukozturk, Ph.D.
Professor of Civil Engineering

Sallie W. Chisholm, Ph.D.
Professor of Civil Engineering
Associate Chair of the Faculty

Jerome Joseph Connor, Jr., Sc.D.
Professor of Civil Engineering

Richard Lawrence de Neufville, Ph.D.
Professor of Civil Engineering
Chairman, MIT Technology and Policy Program

Peter Sturges Eagleson, Sc.D.
Edmund K. Turner Professor of Civil Engineering

Herbert Heinrich Einstein, Sc.D.
Professor of Civil Engineering
(On leave)

Ann Fetter Friedlaender, Ph.D.
Professor of Civil Engineering and Economics
Dean, School of Humanities and Social Science

Ralph A. Gakenheimer, Ph.D.
Professor of Civil Engineering and Urban Studies and Planning

Lynn Walter Gelhar, Ph.D.
Professor of Civil Engineering

Donald R. F. Harleman, Sc.D.
Professor of Civil Engineering
Ford Professor of Engineering

Charles Cushing Ladd, Sc.D.
Professor of Civil Engineering

Steven Richard Lerman, Ph.D.
Professor of Civil Engineering
(On leave)

Robert Daniel Logcher, Sc.D.
Professor of Civil Engineering

Ole Secher Madsen, Sc.D.
Professor of Civil Engineering

Frederick Jerome McGarry, S.M.
Professor of Civil Engineering and Polymer Engineering
Director, Summer Session

Chiang Chung Mei, Ph.D.
Professor of Civil Engineering
(On leave)

Fred Moavenzadeh, Ph.D.
Professor of Civil Engineering
William E. Leonhard Professor of Engineering
Director, Technology and Development Program

François M. M. Morel, Ph.D.
Professor of Civil Engineering
(On leave)

Amedeo Rodolfo Odoni, Ph.D.
Professor of Civil Engineering and Aeronautics and Astronautics
Codirector, Operations Research Center

Frank Edward Perkins, Sc.D.
Professor of Civil Engineering
Dean of the Graduate School

Daniel Roos, Ph.D.
Professor of Civil Engineering
Japan Steel Industry Professsor of Engineering
Director, MIT Center for Technology, Policy, and Industrial Development

Yosef Sheffi, Ph.D.
Professor of Civil Engineering

Joseph Martin Sussman, Ph.D.
Professor of Civil Engineering
Director, Center for Transportation Studies

Daniele Veneziano, Ph.D.
Professor of Civil Engineering

Robert Van Duyne Whitman, Sc.D.
Professor of Civil Engineering

Nigel Henry Moir Wilson, Ph.D.
Professor of Civil Engineering

Associate Professors

Lorna Jane Gibson, Ph.D.
Associate Professor of Civil Engineering
Gilbert W. Winslow Career Development Associate Professor

Philip Michael T. Gschwend, Ph.D.
Associate Professor of Civil Engineering

Harold Field Hemond, Ph.D.
Associate Professor of Civil Engineering

Eduardo Kausel, Ph.D.
Associate Professor of Civil Engineering

Victor C. Li, Ph.D.
Associate Professor of Civil Engineering

Dennis B. McLaughlin, Ph.D.
Associate Professor of Civil Engineering

Wallace Kendall Melville, Ph.D.
Associate Professor of Civil Engineering

S. Shyam Sunder, Sc.D.
Associate Professor of Civil Engineering
Henry L. Doherty Associate Professor of Ocean Utilization

Keith Densmore Stolzenbach, Ph.D.
Associate Professor of Civil Engineering

Assistant Professors

Michael A. Celia, Ph.D.
Assistant Professor of Civil Engineering

Harilaos N. Koutsopoulos, Ph.D.
Assistant Professor of Civil Engineering

John H. Slater, Ph.D.
Assistant Professor of Civil Engineering

Alexander Slocum, Ph.D.
Assistant Professor of Civil Engineering

Duvvuru Sriram, Ph.D.
Assistant Professor of Civil Engineering

Andrew J. Whittle, Ph.D.
Assistant Professor of Civil Engineering

Senior Lecturers

James Martin Becker, Ph.D.
Ignacio Rodriguez-Iturbe, Ph.D.

Lecturers

E. Eric Adams, Ph.D.
Alice Amsden, Ph.D.
Charles C. Caldart, J.D.
Thomas F. Humphrey, S.M.
Henry G. Irwig, Ph.D.
Jack T. Kavanagh, S.B.
John B. Miller, J.D.
James L. Paddock, Ph.D.

Senior Administrative Officer

Trond H. Kaalstad, S.M.

Administrative Assistants

Paulette Chiles
Patricia Dixon
Loretta Hewitt
Maria Marangiello
Shelly Weiner

Technical Writer

Deborah A. Levey

Principal Research Associates

Michael J. Markow, S.M.
Carl D. Martland, C.E.
John Williams, Ph.D.

Research Associates

Sheila L. Frankel, M.A.
John T. Germaine, Ph.D.
Charles H. Helliwell, S.M.
Kenneth R. Maser, Ph.D.

Sponsored Research Staff

Richard Gedney, S.M.
José M. Jimenez, S.B.
John MacFarlane, S.M.

Research Staff, Administrative

Victoria Murphy, B.A.
Ronnie Schwartz, M.B.A.
Patricia Vargas, B.A.

Postdoctoral Associates

Brian Binder, Ph.D.
Mark A. Brzezinski, Ph.D.
Otto von Estorf, Ph.D.
Pascale Nirel, Ph.D.
Neil Martin Price, Ph.D.
Jorge A. Ramirez, Ph.D.

Department of Civil Engineering

(Course 1)

Visiting Engineers

Koji Yamanobe, M.Sc.
Xin Zhao, S.M.

Research Affiliates

Hans Heinrich Herda, Ph.D.
Ravinder Jain, Ph.D.
Robert T. Martin, Ph.D.
Louis Shaffer, Ph.D.
Uri Shamir, Ph.D.

Professors Emeriti

John Melvin Biggs, S.M.
Professor of Civil Engineering, Emeritus

Robert Joseph Hansen, Sc.D.
Professor of Civil Engineering, Emeritus

Myle Joseph Holley, Jr., S.M.
Professor of Civil Engineering, Emeritus

Thomas William Lambe, Sc.D.
Edmund K. Turner Professor of Civil Engineering, Emeritus

John Benson Wilbur, Sc.D.
Professor of Engineering, Emeritus

Civil engineering is the principal instrument for focusing humanity's scientific and technical skills on the creation of constructed facilities, which advance a society toward the attainment of basic objectives such as economic development, environmental protection, and social well-being.

The scope of civil engineering education and research activities at MIT is quite broad and multifaceted. This stems directly from our recognition of the underlying characteristics of the civil engineering projects with which the civil engineer must ultimately deal. Such projects are typically large and costly, with potentially profound environmental, social, and financial impacts. Their design requires the civil engineer to deal with complex technological and scientific issues as well as difficult social and public policy questions. Therefore, our Department's programs emphasize a broad understanding of the highest levels of **technology** available, the behavior of the engineering facility at a **systems** level, and the **management, organizational,** and **institutional** settings within which such engineering systems operate. On the technology dimension, our programs deal with areas such as structural analysis and design, analytical mechanics, geotechnical engineering, materials, hydrodynamics, hydrology, and aquatic science. In the engineering systems area, we focus on such topics as economic analysis, information and computer systems, engineering risk assessment, and operations analysis and optimization. In the management, organizational,and institutional area, we address issues such as management of very large-scale engineering projects, government regulation, industry structure, and institutional issues in engineering project implementation.

Civil engineering professionals are concerned with the critical problems of today's society. For example, our energy needs demand projects of extraordinary scope and potential environmental impact (e.g., the Trans-Alaska Pipeline, offshore extraction facilities). Rebuilding the decaying infrastructure (e.g., highways, bridges, urban water systems) in the United States represents a major technical and economic challenge, as does the construction of new infrastructure in the developing world. The technology of underground facilities for the safe disposal of hazardous wastes and tunnels for transport of people and commodities requires new methodologies for analysis, design, and risk assessment. The efficient transport of goods and people requires innovative systems planning and implementation of infrastructure as well as a basic understanding of the underlying economic, organizational, and political factors. The productivity of natural bodies of water depends upon a deeper understanding of the interaction of manufactured substances with the biological systems existing therein. Ensuring the availability and effective utilization of water for human consumption, irrigation, and power generation, and protection of society from the potential disaster of floods or droughts requires careful planning, design, and operation of facilities as well as an understanding of the demands of society for this resource. Civil engineers play a leadership role in the conception, planning, realization, and operation of facilities and systems that help solve problems in all the above areas as well as others concerned with basic human and societal needs.

As these applications illustrate, civil engineering embraces a broad scope of activities in planning, analysis, design, construction, management, operation, and maintenance of a variety of facility types, activities which are brought to bear on the solution of many kinds of complex, multidimensional problems. It is our belief that the education of civil engineers for future leadership positions should provide a rigorous perspective on the latest technology and analytic methods, as well as on opportunities to develop the social science and management skills that are required to assess needs, evaluate social and environmental impacts, and operate the engineering enterprise. Such opportunities are ensured through a broad curriculum and the encouragement of interactions with other departments at MIT and neighboring universities.

Job opportunities in civil engineering are quite varied. Positions are available in large and small consulting organizations, firms in a variety of industries, and agencies at all levels of government, both in the US and in the international sector. Many of our students build upon the technical, planning, and management skills emphasized in our program to become involved in the entrepreneurial activity of owning and managing their own enterprises. Further, our undergraduate programs are considered excellent entries to graduate study in engineering as well as such fields as law and management.

The Department of Civil Engineering is organized into three functional Divisions: **Constructed Facilities, Transportation Systems, and Water Resources and Environmental Engineering.** These Divisions represent the major professional thrusts of the Department. At the same time, many problems within Civil Engineering transcend any one of these Divisions. This is reflected in the Department's educational and research programs, including those of its Center for Construction Research and Education, which draw upon and integrate the techniques and concepts of the major

Undergraduate Study

functional areas. Detailed descriptions of the programs of the Divisions and the Center are contained in the following pages.

In addition, the Department offers a number of undergraduate and graduate subjects in the following areas: Information Systems and Computational Methods; Analytical Mechanics; Engineering Systems, Economics, and Management; Engineering Risk Assessment and Probabilistic Analysis; and Institutions and Public Policy — which are of interest to students in a variety of fields at MIT.

The Department of Civil Engineering offers two undergraduate curricula for students seeking a strong base for careers in civil engineering or related fields. Course I, which leads to the Bachelor of Science in Civil Engineering, is designed for students having educational goals that fall substantially within the scope of civil engineering. Course I-A, which leads to the Bachelor of Science without designation, is designed for students having a well-defined educational goal, whose attainment requires a specially formulated program of study. Within Course I-A the Department offers special options in Engineering Systems and Computation and in Environmental Science and Engineering.

Each of these curricula provides sufficient flexibility to permit students to develop their own special interests by taking subjects in the Department of Civil Engineering and other departments. Undergraduates are encouraged to participate in the research activities of the Department and in many cases obtain degree credit for such work.

Students often find there are advantages in planning their programs for the third and fourth years so they dovetail with possible graduate study. This is readily accomplished for those students who embark on the Departmental Program in their second year. Under certain circumstances, students are permitted to work toward receiving simultaneously undergraduate and graduate degrees.

Bachelor of Science in Civil Engineering
Course I

The curriculum for this degree is designed to help the student develop problem-solving and decision-making abilities that can be brought to bear on civil engineering problems. The seven-subject core of this curriculum introduces the student to the issues, problems, and methods of civil engineering. It provides a foundation in the areas of analysis and computation, engineering science, and systems and management science, with emphasis on their application to problems that arise within the scope of civil engineering. Planned electives provide useful knowledge of some particular area of civil engineering in depth. This program (including the Internship Option) is accredited by the Accreditation Board for Engineering and Technology.

Bachelor of Science in Civil Engineering
Course I — Internship Option

Students who wish to gain industrial experience as part of their undergraduate and graduate programs may do so by applying to Course I Internship Option. The Engineering Internship Program is described in detail in the School of Engineering section of this chapter; additional information on the Course I Internship Option will be presented here.

The Internship Option requirements are the same as for Course I. In addition, provision is made for students to be employed in the offices, plants, or construction sites of participating companies. The two undergraduate work assignments are together considered equivalent to a 12-unit subject and may, by petition, be used toward the planned electives requirement.

The program is expected to be particularly attractive to students who wish to study for the combined S.B.-S.M. degree, requiring five years for completion. Such students, if admitted to the graduate school, then complete two further work assignments, consisting of the summer and the subsequent fall term following the fourth year. A thesis for the S.M. degree is ordinarily based on the industrial experience. Twelve units of graduate credit are awarded for these two work assignments, in addition to regular thesis credit for preparation of the S.M. thesis.

Students desiring to participate in the Internship Option should apply early in the second term of their sophomore year.

Bachelor of Science in Civil Engineering
Course I

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by 1.01J in the Departmental Program]	8
Science Distribution Requirement [2 subjects can be satisfied by 1.00 or 1.04 and by 18.03 in the Departmental Program]	3
Laboratory Requirement [all or half the requirement can be satisfied by subjects in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units

Subject names below are followed by credit units and by prerequisites if any (corequisites in italics)

Required Subjects: **138—144**

Analysis and Computation

1.00	Introduction to Computers and Engineering Problem Solving[1], 12
1.12	Computer Models of Physical and Engineering Systems, 12; 8.01, 18.02
18.03	Differential Equations, 12; 18.02

Engineering Science

1.04	Behavior of Physical Systems I, 12; 8.01, 18.02
1.05	Behavior of Physical Systems II, 12; 8.01, *18.03*

plus four of the following five subjects:

1.30	Soil Mechanics, 12; 1.04
1.50	Introduction to Structural Engineering, 12; 1.04
1.51	Mechanics of Construction Materials and Structures, 12; 1.04
1.60	Fluid Dynamics, 12; 18.03
1.80	Fundamentals of Ecology, 12

Systems and Management Science

1.01J	Engineering Aspects of Economic Analysis, 12
1.03	Introduction to Probability and Statistics for Engineers, 12; *18.03*

Departmental Laboratory
One of the Departmental offerings that count toward the Institute Laboratory Requirement (1.101, 1.102, 1.105J, 1.106, or 1.107).

Planned Electives: **36**

A selection of three subjects which add depth and/or breadth to the Departmental Program, which meet a stated educational objective, and which are approved by the student's faculty advisor. The selection may include subjects from outside the Department of Civil Engineering.

Units in Departmental Program that also satisfy the General Institute Requirements	**(42 or 48)**
Unrestricted Electives	**48**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

[1] 2.10 may be accepted by petition as substitution for 1.00.

Bachelor of Science as recommended by the Department of Civil Engineering
Course I-A

The programs leading to this degree are provided for those students whose interests and educational goals fall within the field of civil engineering in its broadest sense, but who cannot achieve their goals by meeting the requirements for the undergraduate degree with designation. The Engineering Systems and Computation Option and the Environmental Science and Engineering Option described later are examples of such programs.

Programs leading to this degree are not accredited by the Accreditation Board for Engineering and Technology, an issue that should be discussed with the faculty advisor.

Engineering Systems and Computation (ES&C) Option

This option is designed for students who wish to have a broad engineering-based systems and computation program, but do not wish to satisfy all of the requirements for the Bachelor of Science in Civil Engineering. The program is focused on software and system-analytic tools for dealing with large and complex engineering issues. It prepares students for careers in diverse fields such as engineering model building, applications software development, large-scale systems analysis, engineering application of robotics and automation, and data acquisition and processing.

The ES&C option also provides a general engineering systems and computation basis for people who want to pursue graduate studies in fields such as business management, operations research, planning, engineering project management, as well as further study in application areas such as transportation, energy, the environment, and logistics.

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Bachelor of Science, as recommended by the Department of Civil Engineering
Course I-A
Engineering Systems and Computation (ES&C) Option

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by 1.01J in the Departmental Program]	8
Science Distribution Requirement [2 subjects can be satisfied by 1.00 or 18.03 in the Departmental Program]	3
Laboratory Requirements [all or half the Requirement can be satisfied by subjects in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units

Subject names are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: **114—120**

Analysis and Computation

1.00	Introduction to Computers and Engineering Problem Solving[1], 12
18.03	Differential Equations, 12; 18.02
1.12	Computer Models of Physical and Engineering Systems, 12; 8.01, 18.02

Engineering Systems and Computation

1.01J	Engineering Aspects of Economic Analysis, 12
1.03	Introduction to Probability and Statistics for Engineers, 12; *18.03*

plus four of the following five subjects:

1.02	Optimal Design of Engineering Systems, 12; 1.00
1.06	Probabilistic Models in Engineering, 12; 1.03**
1.07	Engineering Applications of Artificial Intelligence, 12; 6.034**
1.08	Design of Automated and Robotic Systems, 12
1.15	Computer Applications in Statistics, 12; 1.00, 1.03

Departmental Laboratory
One of the Departmental offerings that count toward the Institute Laboratory Requirement (1.101 and 1.102 are particularly relevant).

Planned Electives: **60**

A selection of five subjects which add depth and/or breadth to the Departmental Program, which meet a stated educational objective, and which are approved by the student's faculty advisor. The selection may include subjects from outside the Department of Civil Engineering.

Units in Departmental Program that also satisfy the General Institute Requirements	**(42 or 48)**
Unrestricted Electives	**48**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

Environmental Science and Engineering Option

This option is designed for students who wish to acquire an in-depth knowledge of fundamental physical, chemical, and biological processes coupled with analytical and computational skills suitable for addressing the crucial problems of human impacts on the environment. The program provides the education necessary for careers in environmental engineering, management, and planning and forms a solid foundation for graduate study and research in both basic and applied environmental disciplines.

Bachelor of Science, as recommended by the Department of Civil Engineering Course I-A Environmental Science and Engineering Option

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by 1.01J in the Departmental Program]	8
Science Distribution Requirement [2 subjects can be satisfied by 1.00 or 18.03 in the Departmental Program]	3
Laboratory Requirements [all or half the Requirement can be satisfied by subjects in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Subject names are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	**135—141**
Analysis and Computation	
1.00 Introduction to Computers and Engineering Problem Solving[1], 12	
18.03 Differential Equations, 12; 18.02	
Systems and Management Science	
1.01J Engineering Aspects of Economic Analysis, 12	
1.03 Introduction to Probability and Statistics for Engineers, 12; *18.03*	
Environmental Science and Engineering	
1.05 Behavior of Physical Systems II, 12; 8.01, *18.03*	
1.60 Fluid Dynamics, 12; 18.03	
1.71 Introduction to Hydrology, 12; 1.05	
1.80 Fundamentals of Ecology, 12	
1.85 Waste Water Treatment Engineering, 9; 1.60**	
5.60 Chemical Thermodynamics, 12; *18.02*	
12.23 Environmental Chemistry: Human Impact, 12; 5.60 or 10.13	
Departmental Laboratory	
One of the two following Departmental offerings	
1.106 Laboratory Projects in Environmental Fluid Mechanics, 6	
1.107 Aquatic Chemistry and Biology Laboratory, 12; 5.11	
Planned Electives: A selection of three subjects which add depth and/or breadth to the Departmental Program and that are approved by the student's faculty advisor. This selection may include subjects from outside the Department of Civil Engineering.	**36**
Units in Departmental Program that also satisfy the General Institute Requirements	**(42 or 48)**
Unrestricted Electives	**51**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

Other Course I-A Options

In addition to the Engineering Systems and Computation Option, the Department provides other programs under Course I-A. These programs are available to students who cannot achieve their goals through the Course I or I-A options described earlier. There are five required subjects (1.00, 1.01J, 18.03 and two of the following: 1.03, 1.04, 1.05, 1.12), plus a coherent selection of at least seven planned-elective subjects, which meet a well-defined educational goal. The planned electives are developed in consultation with, and are approved by, a member of the departmental faculty who agrees to serve as the program advisor. Some options specify a number of the planned electives (see, for example, description of the options in Engineering Systems and Computation and in Environmental Science and Engineering).

Electives and Research Opportunities

A list of undergraduate electives in Civil Engineering may be obtained from the Department. Students registered in the Department are encouraged to consider appropriate subjects offered by other departments as part of their elective programs.

Students wishing to work closely with a member of the faculty on research may obtain permission to register for thesis, or to enroll in 1.999 Undergraduate Studies in Civil Engineering. Numerous possibilities for UROP projects exist in the Department. To help undergraduates understand the professional challenges of Civil Engineering as well as help establish working relationships with the faculty, up to ten $600 UROP traineeships are awarded to undergraduates each spring.

*The degree requirements applicable to classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.
1
2.10 may be accepted by petition as substitution for 1.00.

Bachelor of Science in Civil Engineering
Course I

Degree requirements applicable to the Class that entered MIT in September 1985:*

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by 1.01J in the Departmental Program, plus appropriate subjects totaling	63
Science Distribution Requirement can be satisfied by 1.00 or 1.04, and 18.03 in the Departmental Program, plus appropriate subjects totaling	12
Laboratory Requirement can be satisfied by subjects in the Departmental Program, plus an appropriate subject totaling	0 or 6

Departmental Program

Subject names below are followed by credit units and by prerequisites if any (corequisites in italics)

Required Subjects: **138—144**

Analysis and Computation

- 1.00 Introduction to Computers and Engineering Problem Solving[1], 12
- 1.12 Computer Models of Physical and Engineering Systems, 12; 8.01, 18.02
- 18.03 Differential Equations, 12; 18.02

Engineering Science

- 1.04 Behavior of Physical Systems I, 12; 8.01, 18.02
- 1.05 Behavior of Physical Systems II, 12; 8.01, *18.03*

plus four of the following five subjects:

- 1.30 Soil Mechanics, 12; 1.04
- 1.50 Introduction to Structural Engineering, 12; 1.04
- 1.51 Mechanics of Construction Materials and Structures, 12; 1.04
- 1.60 Fluid Dynamics, 12; 18.03
- 1.80 Fundamentals of Ecology, 12

Systems and Management Science

- 1.01J Engineering Aspects of Economic Analysis, 12
- 1.03 Introduction to Probability and Statistics for Engineers, 12; *18.03*

Departmental Laboratory
One of the Departmental offerings that count toward the Institute Laboratory Requirement (1.101, 1.102, 1.105J, 1.106, or 1.107).

Planned Electives: **36**

A selection of three subjects which add depth and/breadth to the Departmental Program, which meet a stated educational objective, and which are approved by the student's faculty advisor. The selection may include subjects from outside the Department of Civil Engineering.

Unrestricted Electives **45—51**

Total Units Required for the S.B. Degree **360**

*The degree requirements applicable to Classes that entered MIT prior to September 1985 can be obtained from the Department.

1
2.10 may be accepted by petition as substitution for 1.00

Bachelor of Science, as recommended by the Department of Civil Engineering
Course I-A
Engineering Systems and Computation (ES&C) Option

Degree requirements applicable to the Class that entered MIT in September 1985:*

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by 1.01J in the Departmental Program, plus appropriate subjects totaling	63
Science Distribution Requirement can be satisfied by 1.00 and 18.03 in the Departmental Program, plus appropriate subjects totaling	12
Laboratory Requirement can be satisfied by subjects in the Departmental Program, plus an appropriate subject totaling	0 or 6

Departmental Program

Subject names are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: **114—120**

Analysis and Computation

- 1.00 Introduction to Computers and Engineering Problem Solving[1], 12
- 18.03 Differential Equations, 12; 18.02
- 1.12 Computer Models of Physical and Engineering Systems, 12; 8.01, 18.02

Engineering Systems and Computation

- 1.01J Engineering Aspects of Economic Analysis, 12
- 1.03 Introduction to Probability and Statistics for Engineers, 12; *18.03*

plus four of the following five subjects:

- 1.02 Optimal Design of Engineering Systems, 12; 1.00
- 1.06 Probabilistic Models in Engineering, 12; 1.03**
- 1.07 Engineering Applications of Artificial Intelligence, 12; 6.034**
- 1.08 Design of Automated and Robotic Systems, 12
- 1.15 Computer Applications in Statistics, 12; 1.00, 1.03

Departmental Laboratory
One of the Departmental offerings that count toward the Institute Laboratory Requirement (1.101 and 1.102 are particularly relevant).

Planned Electives: **60**

A selection of five subjects which add depth and/or breadth to the Departmental Program, which meet a stated educational objective, and which are approved by the student's faculty advisor. The selection may include subjects from outside the Department of Civil Engineering.

Unrestricted Electives **45—51**

Total Units Required for the S.B. Degree **360**

*The degree requirements applicable to Classes that entered MIT prior to September 1985 can be obtained from the Department.
**Alternate prerequisites are listed in the subject description.

Bachelor of Science, as recommended by the Department of Civil Engineering
Course I-A
Environmental Science and Engineering Option

Degree requirements applicable to the Class that entered MIT in September 1985:*

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement [one subject can be satisfied by 1.01J in the Departmental Program]	63
Science Distribution Requirement [2 subjects can be satisfied by 1.00 and 18.03 in the Departmental Program]	12
Laboratory Requirements [all or half the Requirement can be satisfied by subjects in the Departmental Program]	0 or 6

PLUS

Departmental Program **Units**

Subject names are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: **135—141**

Analysis and Computation

- 1.00 Introduction to Computers and Engineering Problem Solving[1], 12
- 18.03 Differential Equations, 12, 18.02

Systems and Management Science

- 1.01J Engineering Aspects of Economic Analysis, 12
- 1.03 Introduction to Probability and Statistics for Engineers, 12; *18.03*

Environmental Science and Engineering

- 1.05 Behavior of Physical Systems II, 12; 8.01, *18.03*
- 1.60 Fluid Dynamics, 12; 18.03
- 1.71 Introduction to Hydrology, 12; 1.05
- 1.80 Fundamentals of Ecology, 12
- 1.85 Waste Water Treatment Engineering, 9; 1.60**
- 5.60 Chemical Thermodynamics, 12; 18.02
- 12.23 Environmental Chemistry: Human Impact, 12; 5.60 or 10.13

Departmental Laboratory

One of the two following Departmental offerings:

- 1.106 Laboratory Projects in Environmental Fluid Mechanics, 6
- 1.107 Aquatic Chemistry and Biology Laboratory, 12; 5.11

Planned Electives: **36**

A selection of three subjects which add depth and/or breadth to the Departmental Program and that are approved by the student's faculty advisor. This selection may include subjects from outside the Department of Civil Engineering.

Unrestricted Electives **48—54**

Total Units Required for the S.B. Degree Beyond the General Institute Requirements **360**

*The degree requirements applicable to Classes that entered MIT prior to September 1985 can be obtained from the Department.
**Alternate prerequisites are listed in the subject description.

Graduate Study

The Department of Civil Engineering grants the following advanced degrees: Master of Science; Master of Science in Civil Engineering; Civil Engineer; Environmental Engineer; Doctor of Science; and Doctor of Philosophy. The Institute's general requirements for these degrees may be found in Chapter IV. Detailed information on the departmental requirements for each degree may be obtained from the Academic Programs Office, Room 1-281.

At the graduate level, research and education go hand-in-hand. Students interested in physical processes or in the analysis and design of component facilities may work in a fundamental area such as soil, water, or structures. Students interested in the planning, design, construction, and operation of large-scale systems of facilities may work in such fields as transportation, water resources, and other public and private systems.

The functional Divisions of the Department and the Center for Construction Research each have responsibility for the administration of the research and academic programs of the Department, including graduate admissions and research assistant, teaching assistant, fellowship and traineeship awards and assignments. Prospective graduate students indicate their preferred affiliation when applying for admission.

Fields of Advanced Study

Integrated programs of advanced study are available in the following areas: geotechnical engineering, structural engineering and mechanics, construction engineering and management, transportation systems, hydrodynamics and coastal engineering, hydrology and water resource systems, water quality control and the aquatic environment, and environmental engineering.

Entrance Requirements for Graduate Study

Applicants do not need to have an undergraduate degree in civil engineering.

Numerous opportunities for graduate education in civil engineering exist for students with backgrounds in other branches of engineering, science, and certain social sciences. These arise through the growth of interdepartmental research and degree programs that bring people of diverse backgrounds together in search of solutions to major societal problems. Graduate students and faculty in the Department have, for example, experience in economics, political science, sociology, architecture, urban and regional planning, management, biology, geology, and oceanography.

Primary requirements for graduate study are a keen intellect combined with capability and interest in quantitative approaches to real problems. Prerequisites for each subject are given in the subject descriptions. Students may make up deficiencies in prerequisites while pursuing a program of graduate study. All applicants are required to submit scores from the GRE Aptitude Test.

Financial Assistance for Graduate Students

The research of the Department is an integral part of the study program, and approximately 100 graduate students each year receive appointments as Research or Teaching Assistants. Most of these appointments fully cover tuition and reasonable living expenses in the Boston area.

In addition to financial support, these appointments provide valuable educational experience and, in the case of Research Assistantships, thesis opportunities.

A number of Fellowships are also available for graduate students.

Divisions, Laboratories, and Special Programs

Constructed Facilities Division

The academic and research programs of the Constructed Facilities Division are concerned with the broad field of development, design, analysis, and assessment of behavior of constructed facilities. Engineering programs in geotechnical engineering and in structural design and analysis build upon subjects in mechanical behavior of materials, engineering mechanics, applied probability and statistics, and computer-based analysis methods in designing a program that meets particular needs and interests. Students may emphasize a particular engineering area or combination, or may focus more on one of several disciplinary areas — including engineering risk assessment, computer-aided engineering, analytical mechanics, and construction automation.

The major areas of research and teaching in the Constructed Facilities Division are:

Geotechnical Engineering. The graduate program in geotechnical engineering emphasizes fundamental principles of mechanics, materials, engineering geology, computational analysis, and analysis of uncertainty — that lay the basis for dealing with the challenging geotechnical engineering problems of the future.

Basic graduate-level subjects in mechanics, dynamics, numerical analysis, and probability are taken jointly with other students studying in Constructed Facilities. A series of subjects dealing with the engineering behavior of soil and rock, and the measurement and evaluation of the properties of these materials, is offered. The approach to the use of fundamental knowledge, site investigation and experience to solve geotechnical engineering problems is developed in subjects dealing with foundations and underground construction. Advanced subjects are offered often every other year — for example, in constitutive modelling, soil dynamics, and underground construction.

The major areas of research are: soft-ground construction, geotechnical aspects of earthquake engineering, underground construction, stability of natural slopes in rock, constitutive modeling of clay and sand, robotics in earthwork engineering, pile foundations, applications of probability and decision theory, mining geotechnics, centrifuge model testing and *in situ* testing — especially for offshore exploration.

Structures and Materials. The graduate program in structures and materials gives students a broad understanding of the behavior of structures and the materials from which they are made. In the academic program, emphasis is placed on structural mechanics, solid mechanics, and the mechanical behavior of construction materials. Additional subjects in numerical methods and risk assessment in engineering are also recommended for students in this program.

The current research program in structures includes projects on computer-aided structural engineering, intelligent structural engineering systems, structural performance of joints in precast concrete segmental bridges, soil-structure interaction under seismic loads, and reliability of structures. In materials, the current research program includes projects on innovative lightweight materials for construction (e.g., fibre-reinforced cements, ceramics, cellular materials, and structural sandwich panels), ice mechanics, ice-structure interaction on offshore structures in the Arctic, and fatigue and multiaxial failure behavior of concrete.

The Geotechnical Engineering Research Laboratory conducts applied and fundamental research on the engineering properties of soil and rock and develops new experimental equipment and field performance of material-structure systems. The underlying objective is to evaluate and improve methods to predict the behavior of constructed facilities through the integration of property measurement, system analysis, and field performance.

Engineering Risk Assessment is important for civil engineering projects, since uncertainties on site characterization, loading, and construction materials are large. In addition, laboratory testing and *in situ* experimentation produce data, the effective interpretation of which requires the use of statistical procedures. The academic program of the Division provides exposure to probability theory, statistics, modeling with random functions, reliability analysis, and risk-based decision methods with an orientation towards civil engineering applications.

Computer-Aided Engineering is based upon the disciplinary areas of information processing, computational methods, and artificial intelligence. A series of specific subjects in theory, methodology, and practice is offered, and applications are integrated in a number of civil engineering subjects.

Analytical Mechanics presents an in-depth treatment of the mechanics of solids and its extension to multiphase media. Students interested in engineering analysis can combine this program with additional geotechnical and structural mechanics subjects.

The Structures Laboratory is an educational facility for studying the behavior of structural elements and structural systems. The special laboratory equipment assists students in relating theoretical predictions to actual response and in visualizing the behavior of complex systems. Students also design and construct models of structural systems that are then tested for verification of the design.

The Advanced Construction Materials Laboratory is both an educational and a research facility. It helps students relate the physical and mechanical properties of construction materials to their compositions. Current research includes mechanical behavior of concrete, asphaltic and cementitious composites, fibrous composites, cellular materials, composite sandwich panels, ceramics, rocks, and ice.

Intelligent Engineering Systems Laboratory (IESL) is comprised of faculty and students whose main interest lies in the applications of artificial intelligence techniques (AI) to engineering problems. Computing facilities include: 3 MicroVAX-IIs, 2 SUN-IIIs, TEKTRONIX graphics workstation, 3 TEKTRONIX 4400 series AI workstations, and 2 APOLLOs. Software includes various AI programming tools and CAD packages.

REMERGENCE

The laboratory for Resource Extraction Materials Energy Reservoir Geotechnical, Environmental, and Construction Engineering provides an intellectual environment and facilities for both theoretical and experimental work with:
- — Natural and construction materials
- — Extraction and construction processes involving those materials, and
- — Structures built in or with those materials.

The REMERGENCE Laboratory is a coordinated, focused endeavor, characterized by the integration of materials, processes, and structures and by a set of disciplines common to the broader branches of engineering involved.

Twenty-five faculty, 10 research staff, and approximately 50 graduate and 50 undergraduate students from the Departments of Civil Engineering; Mechanical Engineering; Ocean Engineering; Materials Science and Engineering; and Earth, Atmospheric, and Planetary Sciences are participating in this laboratory, which has very strong research and teaching components.

Transportation Systems Division

The educational and research programs of the Transportation Systems Division are based on the philosophy that the **analysis, design,** and **implementation** of transportation improvements result from combining 1) quantitative analysis of alternative solutions; 2) an in-depth understanding of specific problem areas spanning freight, passenger, urban, intercity, and international transportation; and 3) knowledge of the economic and institutional setting in which solutions are implemented.

The academic programs of the Division reflect a multi-modal orientation, emphasizing basic methods of analysis and their applications to a range of problems. The approaches include a synthesis of economics, statistics, and mathematical programming, as well as the tools of management and the social sciences. Subject offerings stress both the technical analysis of transportation systems and the social and political factors that must be considered in transportation decisions, including subjects in various applications areas.

The research in the Division also reflects a wide range of methodological and substantive interests. The current major research activities in which students are encouraged to participate include the following: logistics; railroad operations; tracking network planning; travel demand analysis; network equilibration; microcomputer applications in transportation operations; analysis of the US automobile industry; freight and urban passenger transportation in developing countries; regulation in the common-carrier industry; decision support for carrier marketing; transit operations and planning; institutional and organizational issues in transportation; and the relationship between transportation and downtown retail activity.

The faculty, students, and staff of the Transportation Systems Division actively participate in the MIT **Center for Transportation Studies** (CTS), which coordinates transportation research and educational activities at MIT. The interdepartmental degree of **Master of Science in Transportation** is offered in cooperation with the Center for Transportation Studies. Most Civil Engineering students studying transportation at the Master's level are enrolled in this interdepartmental program, although the Master of Science in Civil Engineering degree is still offered for those students whose educational objectives are better

served by that program. Requirements for the Master of Science in Transportation and a detailed description of the Center are contained in Chapter VI.

Water Resources and Environmental Engineering Division — Ralph M. Parsons Laboratory

The programs of graduate study and research include both departmental and interdisciplinary programs in the analytical and managerial aspects of water resources. A joint degree program exists between MIT and the Woods Hole Oceanographic Institution. The educational and research programs are broadly grouped in three areas: **Hydrodynamics, Coastal, and Oceanographic Engineering.** A wide selection of subjects is offered, including theoretical and applied fluid mechanics, hydrodynamics of wave motion, beach erosion and coastal sediment problems, wave interaction in harbors, offshore structures and arctic ice, estuary and coastal circulation and water quality, energy extraction from waves and the ocean thermal gradient, and economic development and environmental impact assessment in the coastal zone. Related subjects in Oceanography and Ocean Engineering are offered by other departments at MIT and at Woods Hole Oceanographic Institution.

Hydrology and Water Resource Systems. Emphasis is on both deterministic and stochastic representations of the hydrologic cycle including hydrometeorology, hydroclimatology, infiltration and runoff production, and groundwater flow. Ongoing investigations cover catchment geomorphology, rainfall modeling and monitoring, global water balance, monitoring network design for surface and groundwaters, reservoir operations, irrigation scheduling, spatial variability in surface and groundwater systems, remote sensing and contaminant transport in groundwaters. Opportunities for participation in several field projects exist. Issues of water resources management and systems technology in solving water problems are also of interest.

Aquatic Science and Environmental Engineering. Major areas of activity include environmental fluid mechanics, aquatic organic and inorganic chemistry, plankton ecology, and the development of analytical techniques for studies of water contaminants and microorganisms. Emphasis is on the integration of hydrodynamic transport and biogeochemical transformation processes in models designed to predict the fate and effects of trace elements and organic compounds in groundwater, rivers, lakes, estuaries, and oceans. Research includes waste heat management, harbor and coastal modeling, local and regional water quality, resource and land use management and facility siting, microorganism/pollutant interaction, phytoplankton growth dynamics, inorganic and organic chemistry of surface and groundwater, and wetland geochemistry.

The **Ralph M. Parsons Laboratory,** which houses the Division, is a major unit for research in the water environment, containing more than 40,000 square feet of classrooms, teaching and research laboratories (eight separate laboratory areas), shops, computer facilities, and offices. Laboratory facilities exist for hydrodynamic studies involving wave motion, jet turbulence and diffusion by means of laser-Doppler instrumentation, flows with thermal and density stratification, and flows in porous media. Research facilities are also available for water analysis including GC-MS, alpha spectrometry, laser correlation spectroscopy, and flow cytometry. A 3-dimensional wave generator has recently been completed. Computer facilities include a local area network of 5 microvax systems and personal computers.

Center for Construction Research and Education

Construction is a multibillion dollar industry and one of the largest sectors of the nation's economy. It creates the buildings, industrial plants, and infrastructure facilities required to serve a broad range of social and economic activities. The construction industry is unique in its size, scope, and strategic importance. It is also unique in the diversity of participants and activities involved in transforming resources of capital, labor, materials, equipment, technology, and management into physical facilities.

The Center for Construction Research and Education provides an intellectual environment and a focal point within MIT for pooling academic and industry resources to address major and fundamental issues of this critically important industry. Since its founding in 1982, the Center has developed comprehensive programs of education, research, and industry interaction, which have earned it a reputation as a center of construction expertise and excellence.

The Center offers graduate degree programs in **Construction Engineering and Management** designed to prepare students for a wide variety of career opportunities, not only in construction firms, but also in owner organizations, government agencies, engineering and design firms, and other companies that supply important materials and products to the industry. Approximately 40 percent of the Center's students are pursuing Ph.D. degrees in preparation for careers in research and teaching. The theoretical foundations of the discipline of construction engineering and management are covered through a wide choice of subjects in the decision sciences, construction management, and construction technology. Students have the flexibility to select other subjects from throughout MIT that are most appropriate to their individual backgrounds and interests.

Through grants, sponsored projects, and Ph.D. thesis research, the Center provides support and direction to a wide range of projects to develop new knowledge and advance the state of the art of construction technology, resources, and management. The Center's Program for Advanced Construction Technology (PACT) focuses directly on developing and adapting new and emerging technologies in such areas as knowledge-based systems, artificial intelligence, advanced engineering materials, automated sensing and condition assessment, and construction robotics. Other Center research projects are seeking insights into new areas of construction demand, such as infrastructure rehabilitation and hazardous waste control in order to identify the implications for financial, labor, equipment, and material resources. The Center's management research projects are addressing a range of strategic and operational issues at the industry, firm, and project levels.

The Center also promotes continuing interaction with the construction industry through a number of activities. For example, it organizes various lectures, seminars, and roundtable meetings that involve industry leaders, faculty, and students in the discussion of critical issues and challenging opportunities in construction. In addition, a construction industry affiliates program provides the basis for more formal and continuous relationships with specific companies involved in the design and construction process.

The Center's programs are leading to a better understanding of the nature of the construction industry and the fundamental changes occurring in its supply and demand. Our goal is to use this understanding to foster the discovery, development, and implementation of advanced technology, analytical methods, and management strategies to improve the industry's productivity, the quality of its products, and its competitiveness in both domestic and international markets.

Computer and Automation Facilities

The Department maintains three networked computer facilities, one in each of its divisions. Major academic and research services are provided on 20 Digital MicroVax IIs and Vax Station IIs using VAX VMS and UNIX operating systems. These machines support a large variety of languages, including FORTRAN, C, PASCAL, and Common LISP; word processing aids including SCRIBE and WPS, and subroutine libraries including IMSL, Pinplot, and SSP; and applications packages including ICES STRUDL, LOGO, ROADS, MAPPS, and the GDS CAD system.

In addition to several clusters of IBM PC/XTs and PC/ATs, the Department maintains a variety of CAD and AI workstations, including SUN 3s and Tektronix 4400s. All machines (except the PCs) are networked together for remote access, file transfer, and electronic mail, and are connected to the outside world through the facilities of the campus network.

To reduce costs and improve productivity and safety, the Department is also doing extensive work in the application of robotics, automation, and remote sensing to problems in construction and infrastructure rehabilitation. A method to efficiently and economically automate construction processes is currently being developed in the Department of Civil Engineering at MIT. Called ICADM (Integrated Construction Automation Design Methodology), the method calls for integrating the designers of the building system — the architect, the building contractor, and the machine designer — and emphasizes the need to simplify machine design by keeping workers in the loop as machine operators.

Current examples of work in progress are the Wallbot (robot to build gypsum walls), the Blockbot (robot to build masonry walls), and Studwelder (robot to weld studs). Additional emphasis is placed on problems of large-scale metrology. Full-scale prototypes of these machines are currently being designed, built, and tested by students from the Departments of Civil Engineering, Mechanical Engineering, and Electrical Engineering and Computer Science.

Interdisciplinary Programs

In responding to the interdisciplinary character of many problems of interest, the Department of Civil Engineering has added faculty with training and professional experience in law, management, economics, political science, and sociology, as well as in mechanical and electrical engineering, ecology, chemistry, and geology. Accordingly, departmental research and subject offerings have been developed in many interdisciplinary areas of current and future importance such as environmental engineering, environmental management and control, public service systems, urban engineering, engineering and public policy, project evaluation and management.

Undergraduates and graduate students can build educational programs in these and other areas, and can select subjects from among the offerings of other departments of the Institute, such as Urban Studies and Planning, Architecture, Management, Mathematics, Economics, Political Science, the life and earth sciences, and the other fields of engineering. Each student's educational and research program may be arranged to reflect his or her personal and professional goals, whether they are intensive or extensive in nature.

Interdisciplinary programs at the graduate level are administered by interdepartmental committees. Those of particular interest to students from civil engineering are in environmental engineering, transportation, materials, applied earth sciences, operations research, computers and information systems, ocean engineering, public systems, the social applications of technology, management of technology, and mineral resources engineering and management.

Master of Science in Technology and Policy

Students interested in applying their civil engineering background to problems of policy, risk assessment and strategic planning for technology may apply for the interdepartmental Master of Science Program in Technology and Policy. This program combines subjects in advanced technology in the particular field of the student's choosing with subjects in economics, systems analysis, political science, and law. General requirements and application procedures are described in Chapter VI.

Master of Science in the Management of Technology

Students who would like to apply their civil engineering background, and at least five years of technical work experience, to issues in technical management may want to explore the Joint Program in the Management of Technology. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, this Program entails a rigorous 12-month curriculum, focusing on management principles for technical people in a technical environment. The Program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program and application procedures are described in Chapter VI.

Joint MIT-Woods Hole Oceanographic Institution Program Course I-W

A joint program with WHOI is intended for students whose primary career objective is oceanographic engineering. Students divide their academic and research efforts between the campuses of the two institutions. While in residence at MIT, students enrolled in this course follow a program similar to that of other students in this Department. The program is described in more detail under the section at the end of this chapter on MIT's Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution.

Mining and Mineral Resources Research Institute

The MMRRI coordinates academic and research activities at MIT in the mineral resources field. The MMRRI and its various academic and research opportunities are described in Chapter VI.

Inquiries

Detailed information about the academic policies and programs of the Department may be obtained by writing to the Academic Programs Office, Room 1-281, MIT, Cambridge, Massachusetts 02139, or by calling (617) 253-7106.

Department of Electrical Engineering and Computer Science

Joel Moses, Ph.D.
Professor of Computer Science and Engineering
Head of the Department

Richard Brooks Adler, Sc.D.
Distinguished Professor of Electrical Engineering and Computer Science
Associate Head of the Department for Electrical Science and Engineering

Fernando José Corbató, Ph.D.
Professor of Computer Science and Engineering
Associate Head of the Department for Computer Science and Engineering

Frederick Clair Hennie III, Sc.D.
Professor of Computer Science and Engineering
Executive Officer

Leonard Abraham Gould, Sc.D.
Professor of Electrical Engineering
Undergraduate Officer
(On leave, fall)

Arthur Clarke Smith, Ph.D.
Professor of Electrical Engineering
Graduate Officer

Professors

Jonathan Allen, Sc.D.
Professor of Electrical Engineering and Computer Science
Director, Research Laboratory of Electronics

Dimitri A. Antoniadis, Ph.D.
Professor of Electrical Engineering
Director, Microsystems Technology Laboratories

Arvind, Ph.D.
Professor of Computer Science and Engineering

Michael Athans, Ph.D.
Professor of Systems Science and Engineering
(On leave, fall)

Arthur Bernard Baggeroer, Sc.D.
Professor of Electrical and Ocean Engineering

Abraham Bers, Sc.D.
Professor of Electrical Engineering

Dimitri P. Bertsekas, Ph.D.
Professor of Electrical Engineering

Amar Gopal Bose, Sc.D.
Professor of Electrical Engineering

Harvey Kent Bowen, Ph.D.
Professor of Electrical Engineering and Ceramic Engineering
Ford Professor of Engineering
Director, Manufacturing and Processing Systems

Louis Benjamin Daniel Braida, Ph.D.
Henry Ellis Warren Professor of Electrical Engineering

James Donald Bruce, Sc.D.
Professor of Electrical Engineering
Vice President for Information Systems

Michael Leonides Dertouzos, Ph.D.
Professor of Computer Science and Electrical Engineering
Director, Laboratory for Computer Science

Alvin William Drake, Sc.D.
Professor of Systems Science and Engineering

Mildred Spiewak Dresselhaus, Ph.D.
Institute Professor
Professor of Electrical Engineering and Physics

Peter Elias, Ph.D.
Edwin S. Webster Professor of Electrical Engineering

David Jacob Epstein, Sc.D.
Professor of Electrical Engineering

Shaoul Ezekiel, Sc.D.
Professor of Electrical Engineering and Aeronautics and Astronautics
Director, Center for Advanced Engineering Study

Clifton G. Fonstad, Jr., Ph.D.
Professor of Electrical Engineering

Lawrence Samuel Frishkopf, Ph.D.
Professor of Electrical and Bioengineering

Robert Gray Gallager, Sc.D.
Professor of Electrical Engineering
Codirector, Laboratory for Information and Decision Systems

Harry Constantine Gatos, Ph.D.
Professor of Molecular Engineering and Electronic Materials

Alan Jay Grodzinsky, Ph.D.
Professor of Electrical and Bioengineering

John V. Guttag, Ph.D.
Professor of Computer Science and Engineering

Hermann Anton Haus, Sc.D.
Institute Professor
Professor of Electrical Engineering
(On leave, spring)

Berthold Klaus Paul Horn, Ph.D.
Professor of Computer Science and Engineering

Erich Peter Ippen, Ph.D.
Elihu Thomson Professor of Electrical Engineering

John Gabriel Kassakian, Sc.D.
Professor of Electrical Engineering
Associate Director, Laboratory for Electromagnetic and Electronic Systems

Robert Spayde Kennedy, Sc.D.
Professor of Electrical Engineering

Jin Au Kong, Ph.D.
Professor of Electrical Engineering

Richard Charles Larson, Ph.D.
Professor of Electrical Engineering

Barbara H. Liskov, Ph.D.
Nippon Electric Company Professor of Software Science and Engineering

Nancy Ann Lynch, Ph.D.
Professor of Computer Science and Engineering

Alan Louis McWhorter, Sc.D.
Professor of Electrical Engineering
Head of the Solid-State Division, Lincoln Laboratory

James Russell Melcher, Ph.D.
Julius A. Stratton Professor of Electrical Engineering and Physics
Director, Laboratory for Electromagnetic and Electronic Systems

Albert Ronald Meyer, Ph.D.
Professor of Computer Science and Engineering

Marvin Lee Minsky, Ph.D.
Donner Professor of Science in the Department of Electrical Engineering and Computer Science

Sanjoy Kumar Mitter, Ph.D.
Professor of Electrical Engineering
Codirector, Laboratory for Information and Decision Systems
Director, Center for Intelligent Control Systems
(On leave, spring)

Frederic Richard Morgenthaler, Ph.D.
Professor of Electrical Engineering
(On leave, fall)

Walter E. Morrow, Jr., S.M.
Professor of Electrical Engineering
Director, Lincoln Laboratory

Alan Victor Oppenheim, Sc.D.
Professor of Electrical Engineering

Ronald Richard Parker, Ph.D.
Professor of Electrical Engineering
Director, Plasma Fusion Center

William Tower Peake, Sc.D.
Professor of Electrical and Bioengineering

Paul Livingstone Penfield, Jr., Sc.D.
Professor of Electrical Engineering
Director, Microsystems Research Center

George Woodman Pratt, Jr., Ph.D.
Professor of Electrical Engineering

Leo Rafael Reif, Ph.D.
Professor of Electrical Engineering

Ronald Linn Rivest, Ph.D.
Professor of Computer Science and Engineering
Associate Director, Laboratory for Computer Science

James Kerr Roberge, Sc.D.
Professor of Electrical Engineering

Jack Philip Ruina, D.E.E.
Professor of Electrical Engineering
Secretary of the Faculty

Jerome Howard Saltzer, Sc.D.
Professor of Computer Science and Engineering
Technical Director, Project Athena

William Francis Schreiber, Ph.D.
Professor of Electrical Engineering

Campbell Leach Searle, S.M.
Professor of Electrical Engineering
(On leave)

Stephen David Senturia, Ph.D.
Professor of Electrical Engineering

Jeffrey Howard Shapiro, Ph.D.
Professor of Electrical Engineering

William McConway Siebert, Sc.D.
Ford Professor of Engineering

Henry I. Smith, Ph.D.
Professor of Electrical Engineering

David Hudson Staelin, Sc.D.
Cecil H. Green Professor of Electrical Engineering

Kenneth Noble Stevens, Sc.D.
Clarence Joseph LeBel Professor of Electrical Engineering

Gerald Jay Sussman, Ph.D.
Professor of Electrical Engineering

Richard Douglas Thornton, Sc.D.
Professor of Electrical Engineering

Donald Eugene Troxel, Ph.D.
Professor of Electrical Engineering

Cardinal Warde, Ph.D.
Professor of Electrical Engineering

Thomas Fischer Weiss, Ph.D.
Professor of Electrical and Bioengineering

David Calvin White, Ph.D.
Ford Professor of Engineering

Alan Steven Willsky, Ph.D.
Professor of Electrical Engineering

Gerald Loomis Wilson, Sc.D.
Vannevar Bush Professor
Professor of Electrical and Mechanical Engineering
Dean, School of Engineering

Patrick Henry Winston, Ph.D.
Professor of Computer Science and Engineering
Director, Artificial Intelligence Laboratory

Associate Professors

Harold Abelson, Ph.D.
Associate Professor of Computer Science and Engineering

Robert Cregar Berwick, Ph.D.
Associate Professor of Computer Science and Engineering
(On leave, fall)

Rodney Allen Brooks, Ph.D.
Associate Professor of Computer Science and Engineering

James G. Fujimoto, Ph.D.
Associate Professor of Electrical Engineering

David K. Gifford, Ph.D.
Associate Professor of Computer Science and Engineering

Shafrira Goldwasser, Ph.D.
Associate Professor of Computer Science and Engineering

William Eric Leifur Grimson, Ph.D.
Matsushita Associate Professor of Computer Science and Engineering

Peter L. Hagelstein, Ph.D.
Associate Professor of Electrical Engineering

Robert Hunter Halstead, Jr., Ph.D.
Associate Professor of Computer Science and Engineering

Carl Eddie Hewitt, Ph.D.
Associate Professor of Computer Science and Engineering

Pierre Amedee Humblet, Ph.D.
Associate Professor of Electrical Engineering

James Logan Kirtley, Jr., Ph.D.
Associate Professor of Electrical Engineering

Jeffrey Hastings Lang, Ph.D.
Associate Professor of Electrical Engineering

Hae-Seung Lee, Ph.D.
Joseph F. and Nancy P. Keithley Career Development Associate Professor of Electrical Engineering

Charles E. Leiserson, Ph.D.
Associate Professor of Computer Science and Engineering
(On leave, fall)

Jae Soo Lim, Ph.D.
Associate Professor of Electrical Engineering

Tomás Lozano-Pérez, Ph.D.
Associate Professor of Computer Science and Engineering
Associate Director, Artificial Intelligence Laboratory

Roger Greenwood Mark, M.D., Ph.D.
Matsushita Associate Professor of Electrical Engineering in Medicine
Codirector, Harvard-MIT Division of Health Sciences and Technology

Silvio Micali, Ph.D.
Associate Professor of Computer Science and Engineering

Bruce Ronald Musicus, Ph.D.
Associate Professor of Electrical Engineering

Terry Philip Orlando, Ph.D.
Associate Professor of Electrical Engineering

Marc H. Raibert, Ph.D.
Associate Professor of Computer Science and Engineering

Martin Frederick Schlecht, Sc.D.
Esther and Harold E. Edgerton Associate Professor of Electrical Engineering

Charles G. Sodini, Ph.D.
Associate Professor of Electrical Engineering

Peter Szolovits, Ph.D.
Associate Professor of Computer Science and Engineering

John N. Tsitsiklis, Ph.D.
Associate Professor of Electrical Engineering

George C. Verghese, Ph.D.
Associate Professor of Electrical Engineering

Stephen Ashley Ward, Ph.D.
Associate Professor of Computer Science and Engineering

William Edward Weihl, Ph.D.
Associate Professor of Computer Science and Engineering

John L. Wyatt, Jr., Ph.D.
Associate Professor of Electrical Engineering

Markus Zahn, Sc.D.
Associate Professor of Electrical Engineering

Assistant Professors

Anant Agarwal, Ph.D.
Assistant Professor of Computer Science and Engineering

Munther A. Dahleh, Ph.D.
Assistant Professor of Electrical Engineering

William J. Dally, Ph.D.
ITT Career Development Assistant Professor of Computer Science and Engineering

Jesús A. del Alamo, Ph.D.
Assistant Professor of Electrical Engineering

Srinivas Devadas, Ph.D.
Assistant Professor of Electrical Engineering

Martha L. Gray, Ph.D.
J. W. Kieckhefer Assistant Professor of Electrical Engineering

Thomas Frederic Knight, Jr., Ph.D.
Assistant Professor of Computer Science and Engineering

Leslie A. Kolodziejski, Ph.D.
Assistant Professor of Electrical Engineering

Raphael Carl Lee, M.D., Sc.D.
Karl R. Van Tassel Career Development Assistant Professor of Electrical Engineering

David Allen McAllester, Ph.D.
Assistant Professor of Computer Science and Engineering

Rishiyur S. Nikhil, Ph.D.
Assistant Professor of Computer Science and Engineering

Ramesh Shrikrishna Patil, Ph.D.
Assistant Professor of Computer Science and Engineering

Martin Schmidt, Ph.D.
Assistant Professor of Electrical Engineering

Jacob K. White, Ph.D.
Assistant Professor of Electrical Engineering

Visiting Professors

Jacob Katzenelson, Sc.D.
Professor of Computer Science and Engineering

Marija Ilic, D.Sc.
Associate Professor of Electrical Engineering

Adjunct Professors

Don P. Clausing, Ph.D.
Bernard M. Gordon Adjunct Professor of Engineering Innovation and Practice

Robert H. Kingston, Ph.D.
Adjunct Professor of Electrical Engineering

Butler W. Lampson, Ph.D.
Adjunct Professor of Computer Science and Engineering

H. Austin Spang III, D.Eng.
Adjunct Professor of Electrical Engineering

Gunter Stein, Ph.D.
Adjunct Professor of Electrical Engineering

Senior Lecturers

Jack Bonnell Dennis, Sc.D.
Harold Eugene Edgerton, Sc.D., D.Eng., L.L.D.
Robert Mario Fano, Sc.D.
Francis Fan Lee, Ph.D.
Thomas H. Lee, Ph.D.
Jerome Ysrael Lettvin, M.D.
Joseph Carl Robnett Licklider, Ph.D.
John Francis Reintjes, M.E.E.
Louis Dijour Smullin, S.M.
Joseph Weizenbaum, S.M., Sc.D. (honoris causa)
Henry Joseph Zimmermann, S.M.

Lecturers

Guy Octo Barnett, M.D.
Stephen Kent Burns, Ph.D.
Chathan M. Cooke, Ph.D.
Charles Freed, S.M.
Bernard Gold, D.E.E.
Hans P. Jenssen, Ph.D.
Alexander Kusko, Sc.D.
Richard S. Marcus, E.E.
Charles E. Miller, S.M.
Ronald S. Newbower, Ph.D.
Charles D. Paton, B.S.
Robert Harvey Rines, Ph.D.
Douglas T. Ross, S.M.
Howard E. Shrobe, Ph.D.
John Avery Tucker, M.Engrg.
Stephen D. Umans, Sc.D.
Bruce D. Wedlock, Sc.D.

Technical Instructors

Charles E. Miller, S.M.
Charles D. Paton, B.S.
Manuel L. Silva, A.E.E.
Douglas J. Young, B.S.

Director of VI-A Internship Program

Kevin J. O'Toole, Nav. E.

Special Assistant to the Department Head for VI-A

John Avery Tucker, M. Engrg.
Lecturer

Administrative Officer

Richard Joseph Caloggero

Facilities Officer

D. Cosmo Papa

Assistants to Laboratory Directors

Phyllis deFano, M.L.S.
Microsystems Technology Laboratories

Barbara Tilson, M.M.
Microsystems Research Center

Educational Computer Facility

Alan Wu, S.B.
Manager

Douglas Alan
Harold Ancell

Administrative Staff

Miriam I. Brooks, B.A.
Peggy Carney
Anne M. Hunter, B.A.
Paul Jerome McQuillan, B.S.
Edward J. Moriarty, S.B.
Marilyn Andrea Pierce
Helen V. Schwartz, M.S.

Senior Research Scientists

David D. Clark, Ph.D.
Nathaniel Isaac Durlach, M.A.
Dennis H. Klatt, Ph.D.
Robert Harmon Rediker, Ph.D.

Principal Research Scientists

John J. Guinan, Ph.D.
Victor Waito Zue, Sc.D.

Research Associates

Wayne R. Burger, Ph.D.
Paul Maciel, A.E.E.
Prabha K. Tedrow, Ph.D.

Research Affiliates

Kenneth J. Germeshausen, S.B.
Gus Kayafas, M.F.A.
Vernon E. MacRoberts
Peter W. Mui, S.B.
Robert Poss, M.D.

Professors Emeriti

Gordon Stanley Brown, Sc.D., D.Ing., Tekn.D.
Institute Professor, Emeritus
Professor of Electrical Engineering, Emeritus

Wilbur Bayley Davenport, Jr., Sc.D.
Professor of Communications Science and Engineering, Emeritus

Jack Bonnell Dennis, Sc.D.
Professor of Computer Science and Engineering, Emeritus

Murray Eden, Ph.D.
Professor of Electrical Engineering, Emeritus

Harold Eugene Edgerton, Sc.D., D.Eng., LL.D.
Institute Professor, Emeritus
Professor of Electrical Measurements, Emeritus

Robert Mario Fano, Sc.D.
Professor of Electrical Engineering and Computer Science, Emeritus

Richard Henry Frazier, S.M.
Professor of Electromechanics, Emeritus

Truman Stretcher Gray, Sc.D.
Professor of Engineering Electronics, Emeritus

Charles Kingsley, Jr., S.M.
Associate Professor of Electrical Engineering, Emeritus

Robert Louis Kyhl, Ph.D.
Professor of Electrical Engineering, Emeritus

Francis Fan Lee, Ph.D.
Professor of Electrical Engineering and Computer Science, Emeritus

Thomas H. Lee, Ph.D.
Professor of Electrical Engineering
Phillip Sporn Professor of Energy Processing, Emeritus

Yuk-Wing Lee, Sc.D.
Professor of Electrical Engineering, Emeritus

Jerome Ysrael Lettvin, M.D.
Professor of Electrical and Bioengineering and Communications Physiology, Emeritus

Joseph Carl Robnett Licklider, Ph.D.
Professor of Electrical Engineering, Emeritus

John Francis Reintjes, M.E.E.
Professor of Electrical Engineering, Emeritus

Walter Alter Rosenblith, Ing. Rad.
Institute Professor, Emeritus
Provost, Emeritus
Professor of Communications Biophysics, Emeritus

Claude Elwood Shannon, Ph.D.
Donner Professor of Science and Professor of Electrical Engineering and Mathematics, Emeritus

Louis Dijour Smullin, S.M.
Professor of Electrical Engineering, Emeritus

Arthur Robert Von Hippel, Ph.D.
Institute Professor, Emeritus
Professor of Electrophysics, Emeritus

Joseph Weizenbaum, S.M., Sc.D. (honoris causa)
Professor of Computer Science and Engineering, Emeritus

Jerome Bert Wiesner, Ph.D.
Institute Professor, Emeritus
President, Emeritus

John McReynolds Wozencraft, Ph.D.
Professor of Electrical Engineering, Emeritus

Henry Joseph Zimmermann, S.M.
Professor of Electrical Engineering, Emeritus

Department of Electrical Engineering and Computer Science

(Course 6)

Undergraduate Study

Many of the products and services in modern society are based upon the work of electrical engineers and computer scientists.

Electrical communication systems involving wires, optical fibers, or wireless technology abound in radio, television, telephone, and computer-communication networks. Modern electronics has made possible sophisticated instrumentation systems for use in all branches of the physical and biological sciences, as well as in most areas of engineering. Electrical machines and electronic circuits control a multitude of systems that deeply affect our lives in many ways. The large quantities of electric power that serve society are provided by electric motors and generators and are controlled and distributed by complex transmission and switching networks.

The tremendous reduction over the last decade in the cost of digital electronic devices has led to an explosive growth in the use of computers and computation. At the same time, our increased understanding of computer science has made possible the development of new software systems of increased power, sophistication, and flexibility.

Modern electronic systems are increasingly digital in nature, exceedingly complex, and would be inconceivable without today's VLSI "chip" technology. Indeed, such systems are so complex that the principles of their design bear great similarities to the design principles of large software systems. Thus, computer science and electronic system design require similar backgrounds in many respects, and computer aids to design are essential in this ever expanding domain of engineering.

The pervasiveness and success of electrical engineering and computer science are due in large part to the conceptual models that electrical engineers and computer scientists have developed for the devices and systems with which they must deal. These models are based upon a background of mathematics and physical sciences, including the fundamental electric and magnetic properties of materials, and are employed in a wide range of applied problems, including both man-made and biological systems. Accordingly, the focus of the undergraduate curricula, and many of the subjects offered for graduate students, is on the fundamental principles and models of the electrical and computer sciences. Elective subjects, laboratory subjects, and thesis research complement this preparation by introducing more specialized techniques of analysis, design, and experimentation in a variety of fields.

The Department's undergraduate programs provide the intellectual tools and skills needed for professional work and form the basis for continuing study and learning that is characteristic of engineering leaders. The heart of the undergraduate programs is a Common Core of subjects (6.001, 6.002, 6.003, and 6.004, each including a laboratory component), which introduces all undergraduate majors in the Department to the principles of organizing computer software and hardware, as well as to the fundamentals of electrical circuits and linear systems. It, as well as many of the required subjects in the separate programs described below, emphasizes mathematical and physical principles along with the techniques used in their application to real problems. Beyond the required subjects, students may elect additional classroom or laboratory subjects of a more specialized nature. Each student's program is developed through personal discussion with, and guidance from, his or her faculty advisor.

The Department offers two undergraduate programs: Program 1, Electrical Science and Engineering; and Program 3, Computer Science and Engineering. Versions of these two programs combining study with industrial engineering practice are available under the designation VI-A. Both programs are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

The curriculum requirements listed for the Department programs are not rigid. Some variations are routinely permitted, while others are considered on an individual basis. Approval of requests for substantial changes may be granted to well-prepared students whose proposed programs are comparable to the listed curricula in breadth, depth, and integrated approach to a well-defined educational objective. Changes affecting the Common Core portion of the curricula, however, are rarely approved.

The major part of each curriculum consists of classroom subjects presented in lecture-recitation format. These subjects provide an organized introduction to the principles and methods of electrical engineering and computer science — an introduction that is reinforced by regularly assigned homework exercises and, in many cases, elementary laboratory or design problems. In addition to these classroom subjects, there are two other important components of each program: laboratory-project subjects and undergraduate thesis.

Laboratory-project subjects expose the student to the design of experiments, equipment, or computer programs; the problems of implementation; and the evaluation of results. Because of the importance of this experience, students are expected to complete one Departmental Laboratory subject in addition to the General Institute Laboratory Requirement.

The undergraduate thesis is the one part of the curriculum in which the student bears the primary responsibility for success. He or she must take the initiative in planning and executing the work and must present the results both orally and in a formal written report. There are deadlines for the completion of these tasks and students must organize their efforts accordingly. Students are encouraged to think about thesis projects early, since preliminary work may begin even in the junior year.

The Departmental programs allow students to choose a number of unrestricted electives, and they are encouraged to select from the areas of science and public policy, engineering management, inventions, entrepreneurship, finance, or managerial economics. Other elective choices might, for example, lead to a "minor" in Program 1 or Program 3, or to gaining more experience with design activities.

All undergraduates are encouraged to acquire industrial experience during their program at MIT. Many aspects of engineering education can be more effectively pursued on the job than in the classroom, especially when students see that the knowledge they have gained at MIT does in fact help to solve real and important engineering problems. This experience may be acquired either through participation in the VI-A Internship Program or through appropriate summer jobs.

Additional information about the Department's undergraduate programs may be obtained from Professor L. A. Gould, Electrical Engineering and Computer Science Undergraduate Office, Room 38-476, MIT, Cambridge, Massachusetts 02139, (617) 253-7329.

Bachelor of Science in Electrical Engineering
Course VI
Program 1: Electrical Science and Engineering

Program 1 prepares students for electrical engineering careers in industry, research, or the academic world. Through a proper selection of elective subjects, students may get a good foundation for an industrial career in one of the specialized branches of electrical engineering or prepare themselves for graduate

study leading to an academic or research career in engineering or such related fields as physics, mathematics, management, or some of the social sciences. Program 1 requires at least one term of mathematics, including differential equations, and one term of quantum physics or thermodynamics, beyond the General Institute Requirements. This background supports and complements the Common Core and the required subjects in electronics, electromagnetic fields, and electrodynamics. Additional restricted electives allow the student to choose from the fields of statistical physics, probability, or advanced mathematics.

The **Bioelectrical Engineering Option** is a variant of Program 1 that prepares students for a variety of careers in biomedical engineering and medicine. The required subjects in this option are the same as those in the normal Program 1 curriculum, with the addition of three subjects in quantitative physiology: 6.021J Cells and Tissues, 6.022J Organ Transport Systems, and 6.023J Sensory and Motor Systems. The restricted elective requirement is satisfied by a single choice from among the subjects 6.041, 18.313, and 18.440. Other modifications may be appropriate for students who have specialized career objectives.

Most students in the Bioelectrical Engineering Option will wish to include several chemistry and biology subjects in their programs. Note that, although 5.11 Principles of Chemical Science, 5.60 Chemical Thermodynamics, and 7.01 General Biology are not specifically required in the Departmental Program, these subjects are prerequisites for many advanced chemistry and biology subjects. Only students with a good high school preparation in chemistry and biology should elect not to take 5.11 and 7.01. Those who may be interested in applying for admission to medical school probably will want to elect additional chemistry and biology subjects, such as 5.310 Laboratory Chemistry, 5.12 Organic Chemistry I, and 7.011 Introduction to Experimental Biology. Further details about the Bioelectrical Engineering Option may be obtained from the Department.

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Complete prerequisites are listed in the subject description.

Bachelor of Science in Electrical Engineering
Course VI
Program 1: Electrical Science and Engineering

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 6.002 and 18.03 in the Departmental Program]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 120

6.001	Structure and Interpretation of Computer Programs, 15
6.002	Circuits and Electronics, 15; 8.02, *18.03***
6.003	Signals and Systems, 15; 6.001, 6.002
6.004	Computation Structures, 15; 6.001, 6.002
6.012	Electronic Devices and Circuits, 12; 6.002, 8.02
6.013	Electromagnetic Fields and Energy, 12; 6.002, 8.02
6.014	Electrodynamics, 12; 6.013
18.03	Differential Equations, 12; 18.02
6.ThU	Undergraduate Thesis, 12

Restricted Electives: 48

1. *One of the following three subjects:*

2.40	Thermodynamics, 12; 8.02, *18.03*
5.60	Chemical Thermodynamics, 12; *18.02*
8.211	Introduction to Quantum Physics, 12; 18.03, 8.02

2. *One subject from each of two of the following three groups:*

Group A.	**Statistical Physics**
6.018	Statistical Mechanics and Thermodynamics, 12; 8.02, 18.03
Group B.	**Probability Theory**
6.041	Probabilistic Systems Analysis, 12; 18.02
18.313	Probability, 12; 18.02
18.440	Probability and Random Variables, 12; 18.02**
Group C.	**Advanced Mathematics**
18.04	Complex Variables with Applications, 12; 18.03
18.063	Introduction to Algebraic Systems, 12; 18.02
18.100	Analysis I, 12; 18.03
18.06	Linear Algebra, 12; 18.02**

3. *One 12-unit subject selected from the Undergraduate Laboratory Subjects 6.100 — 6.182, described in Chapter VIII (in addition to the General Institute Laboratory Requirement)*

Units in Departmental Program that also satisfy the General Institute Requirements	**(27)**
Unrestricted Electives	**48**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**189**

Bachelor of Science in Computer Science and Engineering
Course VI
Program 3: Computer Science and Engineering

Program 3 provides a broad background for careers in computer systems (including both hardware and software aspects) or in sophisticated applications of computers to technical and organizational problems. It also provides a solid preparation for graduate study leading to academic or research careers in computer science and related disciplines. This program includes the Common Core, described earlier, plus required subjects in artificial intelligence, software engineering, and linear and modern algebra. Restricted electives allow the student to choose additional subjects in computer systems or language implementation, theory of computation, algorithms, probability, or robotics.

Although Program 3 is designed for students whose primary professional interest is in computer science and related fields, it also provides the background needed to apply computers in other areas. However, students whose primary professional interest is in the use of computers within a particular discipline may be well advised to undertake their major studies in that discipline with an appropriate selection of elective subjects in computer science.

Bachelor of Science in Computer Science and Engineering
Course VI
Program 3: Computer Science and Engineering

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied from among 6.034 or 6.002, 18.06, and 18.063 in the Departmental Program]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program		Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		120
6.001	Structure and Interpretation of Computer Programs, 15	
6.002	Circuits and Electronics, 15; 8.02, 18.06**	
6.003	Signals and Systems, 15; 6.001, 6.002	
6.004	Computation Structures, 15; 6.001, 6.002	
6.034	Artificial Intelligence, 12; 6.001	
6.170	Laboratory in Software Engineering, 12; 6.001	
18.063	Introduction to Algebraic Systems, 12; 18.02**	
18.06	Linear Algebra, 12; 18.02**	
6.ThU	Undergraduate Thesis, 12	
Restricted Electives:		36
1. *One of the following two subjects:*		
6.033	Computer System Engineering, 12; 6.004	
6.035	Computer Language Engineering, 12; 6.170	
2. *One of the following two subjects:*		
6.044J	Computability, Programming, and Logic, 12; 18.063**	
6.045J	Automata, Computability, and Complexity, 12; 18.063**	
3. *One of the following five subjects:*		
6.036	Problem-Solving Paradigms, 12; 6.034	
6.041	Probabilistic Systems Analysis, 12; 18.02	
6.046J	Introduction to Algorithms, 12; 6.001, 18.063**	
6.801	Machine Vision, 12; 6.003	
6.802	Robot Manipulation, 12; 8.01, 18.02	
Units in Departmental Program that also satisfy the General Institute Requirements		(27)
Unrestricted Electives		48
Total Units Required for the S.B. Degree Beyond the General Institute Requirements		177

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Complete prerequisites are listed in the subject description.

VI-A Internship Program

The VI-A Internship Program combines industrial and research experience with academic work through a series of organized assignments at affiliated companies interwoven with the regular course of study at MIT. Although students may stop at the Bachelor's degree, the Program encourages simultaneous completion of the Bachelor's and Master's degrees by the end of the fifth year with only the Master's thesis required for the two degrees. The work of the final two VI-A internship assignments normally serves as the basis for this thesis. Since the VI-A Internship Program maintains a continuing liaison between the participating companies and the faculty of the Department, students receive assignments of progressive responsibility and sophistication that are usually more professionally rewarding than typical summer jobs. While on internship assignment, students are bona fide employees of the participating company and receive pay as well as academic credit for their work.

Second-year students who are registered and in good standing in any of the regular programs of Course VI may apply for admission to the VI-A Internship Program during the annual selection period in February. The Department cannot guarantee the acceptance of a student into the Program, however, since openings are limited and the participating companies make the final selections.

Students in the VI-A Internship Program usually complete the Bachelor's requirements in the normal four years, including a minimum of two, but occasionally three, internship assignments. Academic credit is earned, while on assignment, by registering for 6.921 VI-A Internship and, when appropriate, 6.922. Students may request to take subjects after hours at sister institutions for transfer credit at MIT, when it is necessary for completion of the Program within the normal time span. VI-A students stopping at the S.B. degree may substitute work done as part of the VI-A Internship Program for the Bachelor's thesis, provided the work is approved by a faculty member and includes both a written report in thesis format and an oral report at MIT or at the company.

Students who wish to receive both a Master's and a Bachelor's degree in the VI-A Internship Program must apply for admission to the MIT Graduate School after the junior year. Students admitted to the combined S.B./S.M. program are normally expected to complete four assignments with their cooperating company.

The companies and laboratories participating in the VI-A Internship Program provide a wide spectrum of assignments in the various fields of electrical engineering and computer science, as well as an exposure to the kinds of activities in which engineers are currently engaged. In all cases, VI-A students must remain with the company with which they start the Program. At the conclusion of the Program, students are not obliged to accept employment with their company, nor is the company obliged to offer such employment.

Additional information about the VI-A Internship Program can be obtained from the Director, Kevin J. O'Toole, VI-A Office, Room 38-473, MIT, Cambridge, Massachusetts 02139, (617) 253-4644.

Engineering Internship Program

Sophomore students in good standing in the Department may apply for admission to the schoolwide Engineering Internship Program (EIP). A general description of this program is provided in the School of Engineering section of this chapter. Like the Department's VI-A Internship Program, the Engineering Internship Program provides a way to combine industrial experience with the Course VI academic program.

Electrical Engineering and Computer Science students who are accepted for the Engineering Internship Program register for the usual program of study in either Program 1 or Program 3. They receive academic credit for their two undergraduate EIP assignments by registering for 6.925.

Participants in the Program are encouraged to apply for admission to graduate school. If they are accepted to and enter graduate school, they complete their work experience with a seven-month assignment at their internship company. They receive graduate academic credit for this assignment by registering for 6.955. In many cases they also satisfy thesis requirements for both the S.B. and the S.M. during the graduate EIP assignment.

Additional information about the Engineering Internship Program as it applies to Electrical Engineering and Computer Science students can be obtained from Professor James K. Roberge, Room 38-494, MIT, Cambridge, Massachusetts 02139, (617) 253-5994.

Graduate Study

Bachelor of Science in Electrical Engineering
Course VI
Program 1: Electrical Science and Engineering

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement		60
Humanities, Arts, and Social Sciences Requirement		72
Science Distribution Requirement can be satisfied by 6.002, 18.03, and either 2.40, 5.60[1], or 8.211 in the Departmental Program.		
Laboratory Requirement		12
Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		120
6.001	Structure and Interpretation of Computer Programs, 15	
6.002	Circuits and Electronics, 15; 8.02, *18.03**	
6.003	Signals and Systems, 15; 6.001, 6.002	
6.004	Computation Structures[2], 15; 6.001, 6.002	
6.012	Electronic Devices and Circuits, 12; 6.002, 8.02	
6.013	Electromagnetic Fields and Energy, 12; 6.002, 8.02	
6.014	Electrodynamics, 12; 6.013	
18.03	Differential Equations, 12; 18.02	
6.ThU	Undergraduate Thesis, 12	
Restricted Electives:		48
1. *One of the following three subjects:*		
2.40	Thermodynamics, 12; 8.02, *18.03*	
5.60	Chemical Thermodynamics, 12; *18.02*	
8.211	Introduction to Quantum Physics, 12; 18.03, 8.02	
2. *One subject from each of two of the following three groups:*		
Group A.	**Statistical Physics**	
6.018	Statistical Mechanics and Thermodynamics, 12; 8.02, 18.03	
Group B.	**Probability Theory**	
6.041	Probabilistic Systems Analysis, 12; 18.02	
18.313	Probability, 12; 18.02	
18.440	Probability and Random Variables, 12; 18.02	
Group C.	**Advanced Mathematics**	
18.04	Complex Variables with Applications, 12; 18.03	
18.063	Introduction to Algebraic Systems, 12; 18.02	
18.100	Analysis I, 12; 18.03	
18.06	Linear Algebra, 12; 18.02	
3. *One 12-unit subject selected from the Undergraduate Laboratory Subjects 6.100 — 6.182, described in Chapter VIII (in addition to the General Institute Laboratory Requirement)*		
Unrestricted Electives		54
Total Units Required for the S.B. Degree		386

Bachelor of Science in Computer Science and Engineering
Course VI
Program 3: Computer Science and Engineering

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement		60
Humanities, Arts, and Social Sciences Requirement		72
Science Distribution Requirement can be satisfied by 6.034 or 6.002, 18.06, and 18.063 in the Departmental Program.		
Laboratory Requirement		12
Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		132
6.001	Structure and Interpretation of Computer Programs, 15	
6.002	Circuits and Electronics, 15; 8.02, 18.06*	
6.003	Signals and Systems, 15; 6.001, 6.002	
6.004	Computation Structures[2], 15; 6.001, 6.002	
6.034	Artificial Intelligence, 12; 6.001	
6.045J	Automata, Computability, and Complexity, 12; 18.063*	
6.170	Laboratory in Software Engineering, 12; 6.001	
18.063	Introduction to Algebraic Systems, 12; 18.02*	
18.06	Linear Algebra, 12; 18.02*	
6.ThU	Undergraduate Thesis, 12	
Restricted Electives:		24
1. *One of the following two subjects:*		
6.033	Computer System Engineering, 12; 6.004	
6.035	Computer Language Engineering, 12; 6.170	
2. *One of the following five subjects:*		
6.036	Problem-Solving Paradigms, 12; 6.034	
6.041	Probabilistic Systems Analysis, 12; 18.02	
6.046J	Introduction to Algorithms, 12; 6.001, 18.063*	
6.801	Machine Vision, 12; 6.003	
6.802	Robot Manipulation, 12; 8.01, 18.02	
Unrestricted Electives		60
Total Units Required for the S.B. Degree		360

*Complete prerequisites are listed in the subject description.

1 5.60 cannot be used to satisfy both the Science Distribution Requirement and the Chemistry portion of the Science Requirement.

2 Students who took 6.032 may use it to satisfy the 6.004 requirement, in which case the total number of units required for the S.B. degree in program 1 will be 363.

The program of graduate education in the Department of Electrical Engineering and Computer Science has three aspects. First, a variety of classroom subjects in physics, mathematics, and fundamental fields of electrical engineering and computer science is offered to permit students to develop strong theoretical backgrounds. Second, more specialized classroom and laboratory subjects and a wide variety of colloquia and seminars introduce the student to the problems of current interest in many fields of research, and to the techniques that may be useful in attacking them. Third, each candidate for any advanced degree conducts research under the direct supervision of a member of the faculty and reports the results in a thesis.

Three advanced degree programs are offered. A well-prepared student enrolled in the Master of Science degree program normally requires about two years to complete formal studies and the required thesis research. With an additional year of study, a student who does superior thesis research can receive the degrees of Electrical Engineer and Master of Science concurrently. The completion of the doctoral program usually takes about five and one-half years beyond the Bachelor's degree. The Department, with rare exception, requires a doctoral candidate to have completed a Master of Science degree at MIT or elsewhere.

There are no fixed programs of study for these degrees. Each student plans a program in consultation with a Graduate Counselor, a member of the faculty whose professional field is related to the student's interest. As the program moves toward thesis research, it usually centers in one of a number of areas, each characterized by an active research program. Areas of specialization in the Department that have active research programs and related graduate subjects include systems, communication, and control; computer science; artificial intelligence; electronics, computers, and systems; electromagnetics and dynamics; energy conversion devices and systems; materials and devices; VLSI system design and technology; communication and probabilistic systems; operations research; optics and quantum electronics; bioelectrical engineering; high-voltage radiation engineering; stroboscopic photography and underwater sound.

In addition to graduate subjects in electrical engineering and computer science, many students find it profitable to study subjects in other departments such as Biology, Economics, Linguistics and Philosophy, Management, Mathematics, Physics, and Brain and Cognitive Sciences.

The informal seminar is an important mechanism for bringing together members of the various research groups. About 16 seminars meet every week. In these, graduate students, faculty, and visitors report their research in an atmosphere of free discussion and criticism. These open seminars are excellent places to learn about the various research activities in the Department.

Research activities in electrical engineering and computer science are carried on by students and faculty in laboratories of extraordinary range and strength, including the Laboratory for Information and Decision Systems, the Research Laboratory of Electronics, the Laboratory for Computer Science, the Artificial Intelligence Laboratory, the Center for Materials Science and Engineering, the Laboratory for Electromagnetic and Electronic Systems, the Energy Laboratory, the Center for Space Research, Lincoln Laboratory, the High-Voltage Research Laboratory, the Media Laboratory, the Francis Bitter National Magnet Laboratory, the Operations Research Center, and the Stroboscopic Light and Pulsed Sonar Laboratory. Full descriptions of many of these laboratories, including a list of current projects, may be found in Chapter VI.

Requirements for Graduate Study

Because the undergraduate backgrounds of applicants to the Department are varied (electrical engineering, computer science, physics, mathematics, biomedical engineering, for example), no specific admissions requirements are listed. The backgrounds of all applicants are studied carefully to assure that they meet the principal prerequisites necessary for their graduate programs. Applicants with unusual academic backgrounds are encouraged to communicate directly with faculty members in their proposed area of study for advice. In any case, superior achievement in undergraduate sciences is considered particularly important.

Master of Science in Electrical Engineering and Computer Science

The general requirements for the degree of Master of Science are given in Chapter IV. The Department requires that the program include at least four formal graduate-level classroom or laboratory subjects (listed as "A" subjects). Students working full time for the Master of Science degree may take as many as four classroom subjects per term. The subjects are wholly elective and are not restricted to those given by the Department. The program of study must be well balanced, emphasizing one or more of the theoretical or experimental aspects of electrical engineering or computer science. A thesis is required.

Electrical Engineer

Able students who desire more extensive training than is possible within the Master of Science program are encouraged to study for the degree of Electrical Engineer. This degree may be awarded for work in either Electrical Engineering or Computer Science. The course of studies for this degree is elective, and a thesis is required. The program ordinarily requires at least four terms of graduate study beyond the Bachelor of Science level. The general requirements for the Engineer's degree are given in Chapter IV. The Department also requires that the program include at least eight approved graduate "A" subjects.

Doctor of Philosophy or Doctor of Science

The general requirements for the degree of Doctor of Philosophy or Doctor of Science are given in Chapter IV. Doctoral candidates are expected to perform thesis work, which is a significant contribution to knowledge, and to participate in the educational program of the Department. Students are normally required to qualify for the Master of Science degree. The quality of the thesis submitted for this degree is a major component in the decision to allow a student to proceed in the doctoral program. Students who enter with a Master's degree must submit evidence of equivalent research accomplishment.

Candidates for the doctoral program in areas other than computer science are required to take a written examination that evaluates their undergraduate preparation for graduate study. This examination is taken in January of the first year of graduate study. An oral examination covering both undergraduate and first-year graduate material is normally taken in the third term of study. An oral examination focused on the student's specific field of study is normally taken in the fifth term.

Doctoral candidates in computer science are required to demonstrate preparation in several areas considered by the faculty to be fundamental to graduate study in computer science at MIT. This is done by taking designated graduate subjects or by taking written examinations in these areas. An oral examination is required when this preparation has been demonstrated, usually during the second graduate year. Another examination with both written and oral components, focused on the student's research area, is taken in the third year.

A thesis examination is required when the thesis research is completed. An approved minor program is also required.

Joint MIT-Woods Hole Oceanographic Institution Program Course VI-W

A joint program with WHOI is intended for students whose primary career objective is oceanographic engineering. Students divide their academic and research efforts between the campuses of the two institutions. The program is described in more detail under the section at the end of this chapter on MIT's Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution.

Other Degree Programs

Graduate students enrolled in the Department participate in several of the interdepartmental degree programs described in detail in Chapter VI. Among those programs are: Biomedical Engineering, Management of Technology Program, Operations Research, and Technology and Policy.

Fellowships and Research and Teaching Assistantships

Studies toward an advanced degree can be supported by personal funds, by an award such as the National Science Foundation Fellowship (which the student brings with him or her to MIT), by a fellowship or traineeship awarded by MIT, or by a graduate assistantship. Assistantships require participation in research or teaching in the Department or in one of the associated laboratories. Assistants normally register for two or three scheduled classroom or laboratory subjects, depending upon the terms of their appointments, and may receive additional academic credit for their participation in the teaching or research program. Many assistants spend two years in a program leading to the simultaneous award of the degrees of Master of Science and Electrical Engineer; the Department encourages assistants to pursue such programs. A brochure on *Research and Graduate Study in Electrical Engineering and Computer Science at MIT*, describing research and teaching opportunities in detail, may be obtained from the Department.

Inquiries

Additional information concerning graduate academic and research programs, admissions, financial aid, assistantships, etc., may be obtained from the Electrical Engineering and Computer Science Graduate Office, Room 38-444, MIT, Cambridge, Massachusetts 02139, (617) 253-4605.

Department of Materials Science and Engineering

Merton Corson Flemings, Sc.D.
Toyota Professor of Materials Processing
Head of the Department

Professors

Benjamin Lewis Averbach, Sc.D.
Professor of Materials Science

Robert Weierter Balluffi, Sc.D.
Professor of Physical Metallurgy

Harvey Kent Bowen, Ph.D.
Professor of Ceramic Engineering and Electrical Engineering
Ford Professor of Engineering
Director, Manufacturing and Processing Systems

Joel Phillip Clark, Sc.D.
Professor of Materials Systems
POSCO Professor of Materials Science and Engineering

Thomas Waddy Eagar, Sc.D.
Professor of Materials Engineering

John Frank Elliott, Sc.D.
Professor of Metallurgy
Director, Mining and Mineral Resources Research Institute

Harry Constantine Gatos, Ph.D., Sc.D. (honoris causa)
Professor of Electronic Materials and Molecular Engineering

Linn Walker Hobbs, D.Phil.
Professor of Ceramics

Keith Huber Johnson, Ph.D.
Professor of Materials Science

Ronald Michael Latanision, Ph.D.
Shell Distinguished Professor of Materials Science
Director, Materials Processing Center

Heather Nan Lechtman, M.A.
Professor of Archaeology and Ancient Technology
Director, Center for Materials Research in Archaeology and Ethnology

Koichi Masubuchi, D.Eng.
Professor of Materials Science and Ocean Engineering
(On leave, spring)

Frederick Jerome McGarry, S.M.
Professor of Polymer Engineering and Civil Engineering
Director of Summer Session

Regis Marc Noel Pelloux, Sc.D.
Professor of Materials Engineering

Robert Michael Rose, Sc.D.
Professor of Materials Science and Engineering

Kenneth Calvin Russell, Ph.D.
Professor of Metallurgy and Nuclear Engineering

Julian Szekely, D.Sc., Ph.D.
Professor of Materials Engineering

Harry Louis Tuller, D.Eng.Sc.
Professor of Ceramics and Electronic Materials
Director, Crystal Physics and Optical Electronics Laboratory

John Bruce Vander Sande, Ph.D.
Professor of Materials Science

August Ferdinand Witt, Ph.D.
Professor of Materials Science
Associate Director, Materials Processing Center

Bernhardt John Wuensch, Ph.D.
TDK Professor of Materials Science and Engineering
Director, Center for Materials Science and Engineering

Ioannis Vassiliou Yannas, Ph.D.
Professor of Polymer Science and Engineering

Gregory John Yurek, Ph.D.
Professor of Metallurgy

Associate Professors

Samuel Miller Allen, Ph.D.
Associate Professor of Physical Metallurgy

Ronald George Ballinger, Sc.D.
Associate Professor of Materials and Nuclear Engineering

Yet-Ming Chiang, Sc.D.
Mitsui Career Development Associate Professor of Contemporary Technology

Gretchen Kalonji, Ph.D.
Associate Professor of Materials Science and Engineering

David Kaye Roylance, Ph.D.
Associate Professor of Materials Engineering

Michael Francis Rubner, Ph.D.
IBM Associate Professor of Polymer Physics

David Albert Rudman, Ph.D.
Pirelli Career Development Associate Professor of Electronic Materials

Donald Robert Sadoway, Ph.D.
Associate Professor of Materials Engineering

Carl Vernette Thompson III, Ph.D.
Associate Professor of Electronic Materials

Assistant Professors

Stuart Bryan Brown, Ph.D.
Richard P. Simmons Assistant Professor of Materials Manufacturing

Peggy Cebe, Ph.D.
Assistant Professor of Polymer Physics

Michael John Cima, Ph.D.
Norton Assistant Professor of Ceramics Processing

Nicole Herbots, Ph.D.
IBM Assistant Professor of Electronic Materials

Andreas Mortensen, Sc.D.
Alcoa Assistant Professor of Mechanical Metallurgy

Visiting Professors

Harold David Brody, Sc.D.
Professor of Metallurgy and Materials Science

Pradeep Kumar Rohatgi, Sc.D.
Professor of Materials Science and Engineering

Adjunct Professors

Lionel C. Kimerling, Ph.D.
Adjunct Professor of Electronic Materials

Robert Alfred Laudise, Ph.D.
Adjunct Professor of Crystallography and Electronic Materials

Senior Lecturers

Michael Berliner Bever, Dr.Jur., M.B.A., Sc.D.
Robert Louis Coble, Sc.D.
Morris Cohen, Sc.D.
Nicholas John Grant, Sc.D.
Walter Shepherd Owen, Ph.D.
David Vincent Ragone, Sc.D.

Lecturer

Joseph Tibor Blucher, Sc.D.

Technical Instructors

Joseph A. Adario
Patrick A. Kearney

Administrative Officer

Joseph Mitti Dhosi, S.M.

Administrative Assistants

Heather Ballinger
Patricia Ellen Gavagan
Ann Austin Jacoby, B.A.
Marguerite A. Meyer, B.A.
Michael O'Connell, B.A.
Hilda Nevius Peirce, B.A.

Senior Research Associates

John Scarseth Haggerty, Sc.D.
Jacek Lagowski, Ph.D.
Robert Charles O'Handley, Ph.D.
Gregory Bruce Olson, Ph.D.

Principal Research Associates

Paul David Bristowe, Ph.D.
James Allen Cornie, Ph.D.
John Forbes Mandell, Ph.D.

Research Associates

Mica Grujicic, Ph.D.
Enrique J. Lavernia, Ph.D.
Reza Najafabadi, Ph.D.

Postdoctoral Associates

Ratnamala Chatterjee, Ph.D.
Gyeong Man Choi, Ph.D.
Frank R. Field III, Ph.D.
Taewook Kang, Ph.D.
Alexana Roshko, Ph.D.
Julie Mae Schoenung, Ph.D.
Andreas F. Schussler, Ph.D.
Peter C. Searson, Ph.D.
Joseph P. Woods, Ph.D.
Seok-Yeol Yoon, Ph.D.

Research Affiliates

Bill C. Giessen, Ph.D.
Ernesto M. Gutierrez, Ph.D.
Joshua J. Jacobs, M.D.
Arthur Linz, Ph.D.

Sponsored Research Staff

David R. Gabbe, Ph.D.
Miriam Rich, A.B.
Leonard Sudenfield

Visiting Scientists

Arlete Cassanho, Ph.D.
Xiao Man Duan, M.S.
Akira Fukano, B.S.
Mark G. Hetherington, Ph.D.
Christian Krarup, M.D.
Genrich L. Krasko, Ph.D.
Jin Liang, M.S.
Tadashi Satoh, Ph.D.
Yoshizo Takai, Ph.D.
Kuihong Yao, B.S.
Xuebin Yu, M.S.

Visiting Scholar

Yin-Lin Xie, B.S.

Professors Emeriti

Michael Berliner Bever, Dr.Jur., M.B.A., Sc.D.
Professor of Materials Science and Engineering, Emeritus

Robert Louis Coble, Sc.D.
Professor of Ceramics, Emeritus

Morris Cohen, Sc.D., D.Tekn.
Institute Professor, Emeritus
Professor of Materials Science and Engineering, Emeritus

Carl Frederick Floe, Sc.D.
Professor of Metallurgy, Emeritus

Nicholas John Grant, Sc. D.
Professor of Metallurgy, Emeritus

William David Kingery, Sc.D.
Ph.D. (honoris causa)
Professor of Ceramics, Emeritus

John Torrey Norton, Sc.D.
Professor of the Physics of Metals, Emeritus

Robert Edward Ogilvie, Sc.D.
Professor of Metallurgy, Emeritus

Walter Shepherd Owen, Ph.D.
Professor of Physical Metallurgy, Emeritus

Cyril Stanley Smith, Sc.D.
Institute Professor, Emeritus
Professor of Metallurgy, Emeritus
Professor of the History of Science and Technology, Emeritus

Herbert Henry Uhlig, Ph.D.
Professor of Metallurgy, Emeritus

Department of Materials Science and Engineering

(Course 3)

Undergraduate Study

Materials science and engineering comprises the generation and application of materials-related knowledge. It is concerned with the structure and properties of materials, and the control of structure and properties through processing. Engineering goals include new materials for improved devices and machines; they also include lower cost materials and processes for improved industrial productivity and competitiveness. Materials science and engineering is critical to all other fields of engineering, and advances in these other fields are often limited by advances in materials.

Materials with which the department concerns itself include electronic materials, ceramics, metals, and polymers. Modern computers and other electronic devices rely heavily on new electronic materials. Similarly, new ceramics and modern metal alloys are critical to high-performance engines including aerospace engines, and polymeric materials continue to show startling improvements for many engineering applications.

Cutting across these four materials classes are the basic science and engineering of materials. Materials science emphasizes the study of the structure of materials and of structure-property relations in materials. It is the physics and chemistry of real materials. Almost all of the properties of importance to an engineer are structure-sensitive; that is, they can be modified in significant ways by changing the chemical composition; the arrangement of the atoms or molecules in crystalline or amorphous configurations; or the size, shape, and orientation of the crystals or other macroscopic units of a solid. To understand how the useful properties of a material can be modified, it is necessary to understand the relationships between structure and properties and how the structure can be changed and controlled by the various chemical, thermal, or mechanical or other treatments to which a material is subjected during manufacture and in use. The fundamental understanding of materials developed through materials science has replaced empiricism as the basis for development of new materials. Whole classes of new materials such as semiconductors, superconductors, and some high-temperature alloys have their roots in modern materials science.

All recent achievements in materials have depended as much on developments in materials engineering as they have on materials science. When developing processes for preparation and production of materials, and when designing materials for specific applications, the modern materials engineer must have a grasp of the modern engineering sciences including heat and mass transfer and chemical kinetics. He or she must also have a proper concern for economic, social, and environmental factors.

Materials processing is a major part of materials engineering. Improved performance of materials depends directly on advances in processing. There are also many examples of challenging engineering problems in reducing the cost and improving the productivity of industrial processing of materials. The Department has strong academic and research activities in all aspects of the processing of materials, as well as in other parts of materials engineering.

The links between materials engineering and materials science are very strong, and the two activities are interwoven in the Department. There are some subjects that all students of materials should know — thermodynamics, kinetics, and certain aspects of solid mechanics, physics, and chemistry. Suitable core subjects in these areas are provided at the undergraduate and graduate levels. In addition, subjects covering a wide variety of topics from solid-state physics to the analysis of materials systems are offered. By the selection of appropriate subjects, the student can follow many different paths through the science and engineering of materials, with emphasis on engineering, science, or a mixture of the two.

Materials science and materials engineering disciplines seek to identify and understand the principles, phenomena, and ideas that are basic to all materials. Many large industries today manufacture products containing a large variety of different materials, and their materials engineers must acquire a working understanding of the basic behavior of all of them. However, there also are many large industries in which a single class of material (e.g., steel, polymers, glasses) is manufactured and processed, and their materials experts must have a knowledge of various aspects of the science and engineering of one class of material. Thus, programs are provided in the Department that enable a student to specialize in the science and engineering of ceramics, electronic materials, metals, or polymers.

Materials engineers and materials scientists, whether generalists or specialists in a particular class of material, are in continuing high demand by industry and government for jobs in research, development, production, and management. They find challenging opportunities in a wide variety of important positions in operations, development, and research in the fast-growing electronics industry, in aerospace, in consumer industries, and in the basic materials preparation and producing industries.

Bachelor of Science in Materials Science and Engineering Course III

The undergraduate program addresses the diverse needs of students who intend to pursue employment or graduate work in the engineering or science of materials. The decision to major in this field may be reached by students as late as the end of the sophomore year.

For these reasons, the curriculum is flexible. Understanding of materials is developed from a foundation of physical and engineering sciences and a core of subjects in mechanics, thermodynamics, crystal structure, and structure-property relations. While these essential subjects are taught within the Department using relevant examples to illustrate the material, appropriate substitutions of subjects taken in other departments are permitted and, indeed, encouraged when a student has somewhat different educational objectives. The degree programs in Course III and Course III-B are accredited by the Accreditation Board for Engineering and Technology, whereas the degree program in Course III-A is not accredited.

The elective program in materials is chosen, with the help of an advisor, to give depth in one or more specific materials areas (metallurgy, ceramics, polymers, electronic materials) and breadth across these areas. The technical areas covered in the elective program include the extraction, preparation, and purification of materials; the processing and fabrication of materials by deformation, heat treatment and phase change; the study and control of structure-property relations in metallic, ceramic, polymeric, and electronic materials; and the physics of solid materials in general. Many graduate subjects are open to undergraduates with the necessary preparation.

Other choices under the elective program are also possible. A student may concentrate elective time on modern production or research management techniques in the materials industry, or on the technology appropriate to a specific industry, or the student may choose a program that provides a sound basis in materials science and engineering from which a coherent graduate program can be developed.

Participation in laboratory work by undergraduates is an integral part of the curriculum. Laboratories are not associated with particular subjects, and, especially in thesis work, the undergraduate student has access to extensive facilities for research in materials.

The teaching facilities, some of which are located in the Center for Materials Science and Engineering and the Materials Processing Center, include an electron-optics laboratory; electron microscopes and microanalyzers; and complete test apparatus for the study of mechanical, thermal, electrical, and magnetic properties. In the ceramics laboratories, most types of refractory as well as electrical ceramics and glasses can be prepared and their properties studied. Facilities for the growth and characterization of metallic and nonmetallic crystals are available. The chemical metallurgy laboratories contain equipment for the study of heat and mass flow and for thermodynamic and kinetic investigations at high temperatures, as well as for the processing of various materials. The materials processing laboratories are equipped for work on deformation, solidification, joining, and vapor deposition as processing techniques. Laboratories in polymer structure and properties, surface chemistry, and corrosion are also open to undergraduates.

Bachelor of Science in Materials Science and Engineering Course III

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 3.00 or 3.11 and by 18.03 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 3.081 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:[1]	111
3.00 Thermodynamics of Materials, 12; 18.02	
3.01 Physical Chemistry of Materials, 12; 3.00**	
3.041 Thesis Seminar, 3	
3.081 Materials Laboratory, 15	
3.10 Chemical Physics of Materials, 12; 3.13, 18.03	
3.11 Mechanics of Materials, 12; 8.01, 18.02	
3.13 Structure of Solids, 12; 8.02	
3.185 Transport Phenomena in Materials Engineering, 12; 3.01, 18.03	
18.03 Differential Equations, 12; 18.02**	
3.ThU Thesis (9 units)[2]	
Restricted Electives:[1]	at least 57
Six of the following subjects, including three from one specific materials area and at least one laboratory:	
Ceramics	
3.06 Glass Science and Engineering, 9; 3.01**, 3.13	
3.069 Ceramics Processing, 9; 3.07, 3.185	
3.07 Introduction to Ceramics, 9; 3.01**, 3.13	
3.075 Ceramics and Glass Laboratory, 12; 3.081, 3.06**	
Electronic Materials	
3.15 Electrical, Optical, and Magnetic Materials and Devices, 9; *3.10*	
3.155J Microelectronics Processing Technology, 12; 3.15	
3.156 Electronic Materials Project Laboratory, 9; 3.155J	
3.16 Electronic Materials, 9; 3.15, 3.155J	
Restricted Electives (continued)	
Metallurgy	
3.02 Crystal Defects and Phase Transformations, 9; 3.01**, 3.13	
3.03 Chemical Metallurgy, 9; 3.185	
3.062 Metals Processing Laboratory, 12; 3.01, 3.081, 3.13	
3.14 Physical Metallurgy, 9; 3.02	
Polymers	
3.062 Polymer Chemistry, 9; 3.091**	
3.063 Polymer Physics, 9; 3.062, 3.00	
3.064 Polymer Engineering, 9; 3.062, 3.11, 3.185	
3.065 Polymer Science Laboratory, 12; 3.081, 3.11	
Units in Departmental Program that also satisfy the General Institute Requirements	(39)
Unrestricted Electives	48—51
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Bachelor of Science Course III-A

Major problems that our society must solve relate to the optimal development and exploitation of our energy, environmental, human, and material resources. Many aspects of materials science and engineering involve diverse considerations that no single department is qualified to handle. A National Academy of Sciences study has shown that while only a small fraction of scientists and engineers receive degrees in materials science and engineering, fully a third of all scientists and engineers are professionally involved in materials-related problems. One of the basic objectives of Course III-A is to provide an opportunity for students to become familiar with the characteristics of materials and with methods used to control and evaluate their properties in parallel with the study of other areas of engineering or science. Generally, a program can be set up to satisfy individual student goals.

Students must submit a complete plan of study to the Department for approval no later than the beginning of their junior year and are required to adhere to this plan. For this reason, students are urged to discuss their plans with appropriate faculty members as early as possible.

1 Substitution of similar subjects may be permitted by petition.
2 Students can elect up to 15 units.

The III-A program is not intended to be used for a double degree program.

The curriculum requirements for Course III-A are similar to, but more flexible than, those for Course III. Four subjects are to be selected from among 3.00, 3.01, 3.10, 3.11, 3.13, 3.185, and 18.03; one laboratory subject from among 3.065, 3.075, 3.081, and 3.082; and three subjects from among the remaining Restricted Electives shown under Course III. In addition, the student and his or her advisor should develop a program of six planned elective subjects, which are not specified in terms of department, in order to attain the goal defined by the student. Further details on the degree requirements and planned elective programs may be obtained from the Department.

Bachelor of Science in Materials Science and Engineering Course III-B

This program provides a student with industrial experience concurrently with academic work through cooperative work assignments matched to the student's capabilities. A faculty advisor is assigned to each student to act, together with a company representative, as co-supervisor during his or her work assignments. Care is taken to ensure a more challenging and rewarding experience than is typical of most summer jobs. Students earn a salary during their work periods and also receive academic credit. Growth in job responsibility is expected as the student progresses.

Admission to the program is preferably obtained during the second year so that the work periods follow during that summer and the summer of the third year. This work program, properly reported, may be used to satisfy the undergraduate thesis requirement.

An option available to students who wish to continue their studies into Graduate School under the auspices of the III-B program is the combined S.B.-S.M. degree, requiring five years for completion. At the end of the senior year, such students then complete two terms of industrial practice and one term of on-campus study, during which time they complete the subject requirements of the S.M. degree. A single thesis, typically based upon the industrial practice, suffices for both degrees. Students exercising this option must follow the normal application procedure to the Graduate School.

Students electing the Engineering Internship Program, which is described in detail at the beginning of the School of Engineering in this chapter, would register in Course III-B.

The curriculum for Course III-B is the same as for Course III, except that 12 units of 3.930/3.931 Industrial Practice are substituted for the thesis. Further details may be obtained from the Department.

Inquiries

Additional information regarding undergraduate programs may be obtained from Professor D. K. Roylance, Room 6-202, MIT, Cambridge, Massachusetts 02139, (617) 253-3309.

Bachelor of Science in Materials Science and Engineering Course III

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 3.00, or 3.11 and by 18.03 in the Departmental Program, plus appropriate subjects totaling	12
Laboratory Requirement can be satisfied by 3.081 in the Departmental Program.	

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects:[1]		111—117
3.00	Thermodynamics of Materials, 12; 18.02	
3.01	Physical Chemistry of Materials, 12; 3.00*	
3.041	Thesis Seminar, 3	
3.081	Materials Laboratory, 15	
3.10	Chemical Physics of Materials, 12; 3.13, 18.03	
3.11	Mechanics of Materials, 12; 8.01, 18.02	
3.13	Structure of Solids, 12; 8.02	
3.185	Transport Phenomena in Materials Engineering, 12; 3.01, 18.03	
18.03	Differential Equations, 12; 18.02*	
3.ThU	Thesis (9 to 15 units)	

Restricted Electives:[1]		at least 57

Six of the following subjects, including three from one specific materials area and at least one laboratory:

Ceramics	
3.06	Glass Science and Engineering, 9; 3.01*, 3.13
3.069	Ceramics Processing, 9; 3.07, 3.185
3.07	Introduction to Ceramics, 9; 3.01*, 3.13
3.075	Ceramics and Glass Laboratory, 12; 3.081, 3.06*

Restricted Electives (continued)	
Electronic Materials	
3.15	Electrical, Optical, and Magnetic Materials and Devices, 9; *3.10*
3.155J	Microelectronics Processing Technology, 12; 3.15
3.156	Electronic Materials Project Laboratory, 9; 3.155J
3.16	Electronic Materials, 9; 3.15, 3.155J
Metallurgy	
3.02	Crystal Defects and Phase Transformations, 9; 3.01*, 3.13
3.03	Chemical Metallurgy, 9; 3.185
3.082	Metals Processing Laboratory, 12; 3.01, 3.081, 3.13
3.14	Physical Metallurgy, 9; 3.02
Polymers	
3.062	Polymer Chemistry, 9; 3.091*
3.063	Polymer Physics, 9; 3.062, 3.00
3.064	Polymer Engineering, 9; 3.062, 3.11, 3.185
3.065	Polymer Science Laboratory, 12; 3.081, 3.11

Unrestricted Electives	up to 48
Total Units Required for the S.B. Degree	**360**

*Alternate prerequisites are listed in the subject description.

1 Substitution of similar subjects may be permitted by petition.

Graduate Study

Departmental Degrees

The Department offers the degrees of Doctor of Philosophy and Doctor of Science in Ceramics, in Electronic Materials, in Materials Engineering, in Materials Science, in Metallurgy, and in Polymers. It offers the degrees of Master of Science in these same fields and also offers the degrees of Materials Engineer and Metallurgical Engineer.

The fields are described briefly below. A description of 15 to 20 elective subjects in each of these fields is provided in Chapter VIII and in literature available from the Department. The subjects 3.20 Thermodynamics of Materials and 3.21 Kinetic Processes in Materials are basic to all degree programs and constitute a required core for all graduate students enrolled in doctoral programs in the Department. This requirement may be waived upon petition to the Departmental Committee on Graduate Students if it may be demonstrated that equivalent coverage of this material has been secured in previous study.

Ceramics. The field of ceramics is concerned with the science and engineering involved in the manufacturing, processing, and utilization of a wide range of inorganic materials, including oxides, nitrides, carbides, silicates, and more complex compounds. Ceramic materials are essential to many diverse industries. In recent years a large research and development effort has resulted in important extensions of the useful properties of traditional ceramics and has led to the development of many exciting new materials. The core subjects are 3.20 Thermodynamics of Materials and 3.21 Kinetic Processes in Materials.

Electronic Materials. The field of electronic materials is concerned with the science and technology of materials for semiconducting, magnetic, optical, and superconducting device applications. It is further concerned with the design and realization of useful materials through understanding and control of the interplay between electronic processes and structural aspects — atomic arrangements, defects, interfaces, and phase constitution and morphology. Research within this field includes electronic materials processing in bulk and thin-film form; characterization of the semiconducting, optical, and magnetic properties of crystalline and amorphous materials in relation to their microstructure and composition; and theoretical and experimental study of the electronic characteristics of solid-solid, -liquid, and -gas interfaces and their implications for devices. In addition to 3.20 and 3.21, the core subjects are 3.43 Physics and Chemistry of Materials, 3.46 Electronic Materials and Devices, 3.47 Electronic Materials Processing, and 6.732 Physics of Solids.

Materials Engineering. Materials engineering is concerned with technically and economically feasible solutions to problems of materials production and utilization. It involves the synthesis of fundamental and practical knowledge to develop, produce, modify, and apply materials to meet specific needs. Research within the field involves issues relating to physical and chemical aspects of materials extraction, production and utilization, to problems of innovation, costs, quality, and reliability, and to societal and environmental concerns. In addition to 3.20 and 3.21, the core subjects are 3.55 Macroscopic Transport in Materials Processing and 3.56 Engineering Systems Analysis.

Materials Science. Materials science is the study of common principles and fundamental phenomena that underlie the structure and properties of a wide range of materials — metals, ceramics, polymers, and electronic materials — which are frequently used in combination. The common principles involved are those associated with electronic structure and bonding, atomic arrangement, phase stability, and the role of imperfections and microstructure. Fundamental phenomena considered include structural and phase transformations; reactivity; mass and charge transport; interface behavior; and the optical, electronic, and mechanical responses to internal and external stimuli. In studying these principles and phenomena, materials science employs many characterization approaches, drawing heavily on diffraction and imaging methods, as well as microanalysis and computer modeling, to provide coherent descriptions of materials structure and structural imperfections to which particular materials properties can be ascribed. In addition to 3.20 and 3.21, the core subjects are 3.271 Structure of Materials, 3.31 Phase Transformations, 3.33 Defects in Crystals, and 3.43 Physics and Chemistry of Materials.

Metallurgy. This well-established discipline encompasses the study of metallic materials, elemental, alloy, and composite. It includes the processing of ores and minerals; extracting and refining of metals by chemical processes; the melting, alloying, and casting of metals; and control of structure by techniques such as heat treatment and mechanical working. The relations between composition, structure, and properties of metallic materials and the study of the behavior of metals under service conditions are important parts of the field. Metallurgy is viewed as a coherent discipline and all candidates are expected to have a working knowledge of both chemical and physical areas — though not usually to the same depth. Suitable programs are likely to be individualistic, and may be constructed in a number of ways from the various subjects available. In addition to 3.20 and 3.21, the core subjects are 3.40J Physical Metallurgy and 3.50 Physical Chemistry of Metallurgical Processes.

Polymers. Synthetic high polymers, "plastics," are long molecules, the principal constituents of which are typically carbon, hydrogen, oxygen, chlorine, and a few other elements. Because of the unusual nature of carbon bonding, an infinite number of combinations can be conceived and produced, with virtually all exhibiting low specific gravity, ease of melt forming, and a wide range of properties, depending upon composition, structure, and processing history. Both the science and the engineering of materials have reached a high level of sophistication in this field: linear, cross-linked, crystalline, amorphous, oriented, glassy, rubbery, strong, stiff, homopolymers, copolymers, terpolymers, blends, transparent, opaque, filled, reinforced, alloys, composites, laminates, and adhesives are but a few of the descriptive aspects that can be controlled and manipulated to achieve a desired profile of properties.

Numerous opportunities exist for a student to concentrate on specific areas of polymer science or engineering: physical properties, mechanical behavior, chemical synthesis and modification, surface characteristics, environmental interactions, and combinations with other substances are a few examples. Each student pursues a particular program of study and research consistent with individual interests. In addition to 3.20 and 3.21, the core subjects are 3.91J Mechanical Behavior of Plastics, 3.93J Thermal Transitions, Optical and Electrical Behavior of Polymers, and 10.691 Synthesis of Polymers.

The various graduate fields are not separated by sharp boundaries. Each member of the departmental faculty works in at least two of these fields and a number of subjects appear in common on the lists of elective subjects in each degree program; there is a great deal of interaction between the fields. The graduate fields are also coupled to other activities on materials within the Institute. Faculty from other departments participate in the departmental teaching and research in these fields. Subjects offered by other departments are, whenever appropriate, included in the recommended electives, and many departmental students participate in multidisciplinary research projects with students and faculty from various parts of the Institute.

Students are expected to learn the fundamentals of their chosen field and to develop a deep understanding of one or more significant aspects of it. The general examinations for the doctoral degree are designed accordingly. A full range of advanced-level subjects is offered in each graduate field. In addition, arrangements can be made for individually planned study of any topic. Apart from 3.20 and 3.21, students are not required to take any specified subjects, but it is strongly recommended that they take further appropriate core subjects unless they have taken equivalent subjects earlier in their careers. The selection of subjects and decisions about combinations of subjects that constitute a minor usually require much thought by the student, as well as consultation with faculty advisors.

A large and active research program on the structure and properties, preparation, and processing of materials, with emphasis on ceramics, metals, polymers, and electronic materials, is conducted in the Department. Graduate research is an important part of the educational process and much emphasis is placed on the research thesis. Students choose research projects from many alternative opportunities that exist within the Department, and work closely with an individual faculty member. The results of the research must be of sufficient significance to warrant publication in the scientific literature. There are a large number of well-equipped research laboratories in the Department, and there is much interaction between them, including sharing experimental facilities and equipment. Most members of the Department also are members of the Center for Materials Science and Engineering, which provides and maintains excellent central facilities including a machine and instrument shop. The Center promotes interdisciplinary research on materials and is described in Chapter VI.

Master of Science in the Management of Technology

Students who would like to apply their materials science and engineering background and at least five years of technical work experience to issues in technical management may want to explore the Management of Technology Program. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, this Program entails a rigorous twelve-month curriculum, focusing on management principles for technical people in a technical environment. The Program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program and application procedures are described in Chapter VI.

Master of Science in Technology and Policy

Students interested in applying their materials science and engineering background to problems of policy and socioeconomic assessment of technology may apply for the interdepartmental Master of Science Program in Technology and Policy. This program combines subjects in advanced technology in the particular field of the student's choosing with subjects in economics, systems analysis, political science, and law. General requirements and application procedures are described in Chapter VI.

Master of Science in Materials Science and Engineering and Management

Students planning on applying their Engineering education to a career in the manufacturing industry may apply for the 24-month Leaders for Manufacturing Program. The rigorous program combines subjects in advanced technology with subjects in management, and involves on-site research work and close cooperation with manufacturing companies. The Program is offered jointly through the Sloan School of Management and the Departments of Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science, and Mechanical Engineering in the School of Engineering. General requirements and application procedures are described in Chapter VI.

Mineral Resources Engineering and Management

Students in the Department with interests in the scientific, technical, and policy aspects of mineral resources can find related programs of study and research in the areas of metallurgy, ceramics, and materials engineering. These activities are also coordinated with the interdisciplinary program in Mineral Resources Engineering and Management described in Chapter VI.

Simultaneous Award of Two Master of Science Degrees for Students from Other Departments

Graduate students may seek two Master of Science degrees simultaneously or in sequence, one awarded by the student's home department and the other by the Department of Materials Science and Engineering. The rules covering the matter are found in Chapter IV. Additional information on requirements that must also be met to obtain the Master of Science degree from the Department of Materials Science and Engineering may be obtained from the Department.

Joint MIT-Woods Hole Oceanographic Institution Program Course III-W

A joint program with WHOI is intended for students whose primary career objective is oceanographic engineering. The program is described in more detail under the section at the end of this chapter on MIT's Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution.

Requirements for Completion of Graduate Degrees

The general requirements for completion of graduate degrees are described in Chapter IV. Students completing a Master of Science degree are required to present a seminar summarizing the thesis. The Department requires that candidates for the doctoral degrees go through a qualifying procedure before continuing with their programs of study and research, and that they satisfy a minor requirement. Information on this procedure and on the areas covered by the general examination is available from the Chairman of the Departmental Committee on Graduate Students.

Entrance Requirements for Graduate Study

The general admissions requirements are given in Chapter IV. Programs are arranged on an individual basis depending upon the preparation and interests of the student. Those who have not studied some thermodynamics and kinetics at the undergraduate level are advised to take 3.01 Physical Chemistry of Materials and 3.02 Crystal Defects and Phase Transformations. Students wishing to do graduate work in ceramics are asked to take 3.07 Introduction to Ceramics unless they have had a similar subject in their undergraduate programs.

Teaching and Research Assistantships

The Department offers assistantships and fellowships for graduate study. Research and teaching assistantships are available in the fields in which the Department is active.

Inquiries

Additional information regarding graduate programs, admissions, financial aid, etc., may be obtained by writing to the Chairman of the Departmental Committee on Graduate Students, Professor S. M. Allen, Room 8-303, MIT, Cambridge, Massachusetts 02139, (617) 253-3329.

Department of Mechanical Engineering

David Neal Wormley, Ph.D.
Professor of Mechanical Engineering
Head of the Department

Professors

Ali Suphi Argon, Sc.D.
Quentin Berg Professor of Mechanical Engineering

Stanley Backer, Sc.D.
Professor of Mechanical Engineering

Klaus-Jürgen Bathe, Ph.D., D.Sc.
Professor of Mechanical Engineering
(On leave)

Stephen Harry Crandall, Ph.D.
Ford Professor of Engineering

Ernest George Cravalho, Ph.D.
Edward Hood Taplin Professor of Medical Engineering
Associate Director of the Harvard-MIT Division of Health Sciences and Technology

Clarence Forbes Dewey, Jr., Ph.D.
Professor of Mechanical Engineering

Steven Dubowsky, Sc.D.
Professor of Mechanical Engineering
Associate Director, Laboratory for Manufacturing and Productivity
(On leave)

James Alan Fay, Ph.D.
Professor of Mechanical Engineering

Woodie Claude Flowers, Ph.D.
Professor of Mechanical Engineering

Peter Griffith, Sc.D.
Professor of Mechanical Engineering

Elias Panayiotis Gyftopoulos, Sc.D.
Ford Professor of Engineering
Professor of Mechanical and Nuclear Engineering

J. Karl Hedrick, Ph.D.
Professor of Mechanical Engineering
(On leave)

John Benjamin Heywood, Ph.D., D.Sc.
Professor of Mechanical Engineering
Director, Sloan Automotive Laboratory

Roger Dale Kamm, Ph.D.
Professor of Mechanical Engineering

James Collyer Keck, Ph.D.
Ford Professor of Engineering

Patrick Leehey, Ph.D.
Professor of Mechanical and Ocean Engineering

Padmakar Pratep Lele, M.D., Ph.D.
Professor of Experimental Medicine

Richard Harold Lyon, Ph.D.
Professor of Mechanical Engineering

Robert Wellesley Mann, Sc.D.
Whitaker Professor of Biomedical Engineering

Frank Ambrose McClintock, Ph.D.
Professor of Mechanical Engineering

Borivoje Budimira Mikić, Sc.D.
Professor of Mechanical Engineering

Ronald Filmore Probstein, Ph.D.
Professor of Mechanical Engineering

Ernest Rabinowicz, Ph.D.
Professor of Mechanical Engineering

Thomas Brown Sheridan, Sc.D.
Professor of Engineering and Applied Psychology

Joseph Leconte Smith, Jr., Sc.D.
Professor of Mechanical Engineering

Ain Ants Sonin, Ph.D.
Professor of Mechanical Engineering

Nam Pyo Suh, Ph.D.
Professor of Mechanical Engineering

James Henry Williams, Jr., Ph.D.
Professor of Mechanical Engineering

David Gordon Wilson, Ph.D.
Professor of Mechanical Engineering

Gerald Loomis Wilson, Sc.D.
Vannevar Bush Professor
Professor of Electrical and Mechanical Engineering
Dean, School of Engineering

Ioannis Vassiliou Yannas, Ph.D.
Professor of Polymer Science and Engineering

Associate Professors

Rohan Abeyaratne, Ph.D.
Associate Professor of Mechanical Engineering

Triantaphyllos R. Akylas, Ph.D.
Associate Professor of Mechanical Engineering
Henry L. Doherty Professor in Ocean Utilization

Lallit Anand, Ph.D.
Associate Professor of Mechanical Engineering

Haruhiko Asada, Ph.D.
Associate Professor of Mechanical Engineering

Wai Kong Cheng, Sc.D.
Associate Professor of Mechanical Engineering
(On leave)

Michael Patrick Cleary, Ph.D.
Associate Professor of Mechanical Engineering

Ahmed Fouad Ghoniem, Ph.D.
Associate Professor of Mechanical Engineering

David Clair Gossard, Ph.D.
Associate Professor of Mechanical Engineering

Timothy George Gutowski, Ph.D.
Associate Professor of Mechanical Engineering

David Edgar Hardt, Ph.D.
Associate Professor of Mechanical Engineering
Director, Laboratory for Manufacturing and Productivity

Neville Hogan, Ph.D.
Associate Professor of Mechanical Engineering

David Moore Parks, Ph.D.
Associate Professor of Mechanical Engineering

Anthony T. Patera, Ph.D.
Associate Professor of Mechanical Engineering

Igor Paul, Sc.D.
Associate Professor of Mechanical Engineering

Carl Richard Peterson, Sc.D.
Associate Professor of Mechanical Engineering

Derek Rowell, Ph.D.
Associate Professor of Mechanical Engineering

Warren Paul Seering, Ph.D.
Associate Professor of Mechanical Engineering

Ming-Kai Tse, Ph.D.
Mitsui Associate Professor of Mechanical Engineering

Assistant Professors

Mary Cunningham Boyce, Ph.D.
Bradley Foundation Assistant Professor of Mechanical Engineering

George Chryssolouris, Ph.D.
Assistant Professor of Mechanical Engineering

William K. Durfee, Ph.D.
Keck Foundation Assistant Professor of Mechanical Engineering

Mark J. Jakiela, Ph.D.
Assistant Professor of Mechanical Engineering

Steven H. Kim, Ph.D.
Assistant Professor of Mechanical Engineering

Harri Kytomaa, Ph.D.
Atlantic Richfield Assistant Professor of Mechanical Engineering

John H. Lienhard V, Ph.D.
George N. Hatsopoulos Assistant Professor of Mechanical Engineering

Shahryar Motakef, Ph.D.
Assistant Professor of Mechanical Engineering

Patricia Renaud, Ph.D.
Edgerton Assistant Professor of Mechanical Engineering

Emanuel Sachs, Ph.D.
Rockwell International Assistant Professor of Mechanical Engineering

Jean-Jacques E. Slotine, Ph.D.
Assistant Professor of Mechanical Engineering
Henry L. Doherty Professor of Ocean Utilization

Harry West, Ph.D.
Mitsui Assistant Professor of Mechanical Engineering

Kamal Youcef-Toumi, Sc.D.
Carl Richard Souderberg Assistant Professor of Mechanical Engineering

Adjunct Professor

Ernesto Enrique Blanco, B.M.E.
Adjunct Professor of Mechanical Engineering

Senior Lecturers

John Patrick Appleton, Ph.D.
John Francis Burke, M.D.
Nathan Henry Cook, Sc.D.
Carlo John DeLuca, Ph.D.
Leon Robert Glicksman, Ph.D.
Jacob Pieter Den Hartog, Ph.D., D.Eng., D.Appl.Sc., D.Tech.Sc., D.Sc. (honoris causa)
Philip Aldrich Drinker, Ph.D.
William Hamilton Harris, M.D.
George Nicholas Hatsopoulos, Sc.D.
Charles Edward Huggins, M.D., Ph.D.
Henry Martyn Paynter, Sc.D.
Warren Max Rohsenow, D.Eng.
Ascher Herman Shapiro, Sc.D.
Giuliana Cavalieri Tesoro, Ph.D.
Tau-Yi Toong, Sc.D.
Caroline Whitbeck, Ph.D.

Lecturers

Adam Carr Bell, Sc.D.
Thomas Percival Bligh, Ph.D.
Emanuel S. Bobrov, Ph.D.
Edgar Hiel Bristol II, S.B.
David Eisenhaure, M.E.
Lewis Erwin, Ph.D.
Jeffrey Joseph Fredberg, Ph.D.
Ralph Frederick Goldman, Ph.D.
Cheryl Goodenough-Trepagnier, Ph.D.
James B. Grinnell, Jr., M.Ind.Ed.
William Peter Hansen, Jr., Ph.D.
Wilson C. Hayes, Ph.D.
Michael Hercher, Ph.D.
W. Andrew Hodge, Ph.D.
James Hubbard, Ph.D.
David Guild Jansson, Sc.D.
James Kirk, M.B.A.
Milos Konopasek, Ph.D.
Zvi Ladin, Ph.D.
Philip Franz Meyfarth, Ph.D.
Michael Packer, Ph.D.
George Pariseanu, Sc.D.
Michael James Rosen, Ph.D.
Nannaji Saka, Sc.D.
J. Kenneth Salisbury, Jr., Ph.D.
William Charles Unkel, Ph.D.
Jose Venegas, Ph.D.
Daniel Eugene Whitney, Ph.D.
Victor Wong, Ph.D.
Dana Russell Yoerger, Ph.D.

Technical Instructors

William Eugene Bachman, B.A.
Joseph Anthony Caloggero
Frederick Paul Cote, B.A.
James Briggs Grinnell, Jr., M.Ind.Ed.
Robert Francis Kane, B.S.M.E.

Administrative Officer

William James Westcott

Administrative Staff

John F. O'Brien, Jr., M.S.A.
Peggy Garlick, A.S.
Leslie M. Regan

Senior Research Engineer

Yukikazu Iwasa, Ph.D.

Senior Research Scientist

Stanley B. Gershwin, Ph.D.

Principal Research Scientists

Michael James Rosen, Ph.D.
Nannaji Saka, Sc.D.

Senior Research Associate

David Parks Hoult, Ph.D.

Research Associate

Eugene M. Skrabut, S.M.

Research Engineers

Ralph Gordon Burgess, S.B.
Richard R. Fenner, B.S.
Mark C. Johnson, S.M.

Postdoctoral Associates

Said Ahzi, Ph.D.
Marcus Brede, D.Sc.
Daniel Dewey, Ph.D.
Samuel Landsberger, Ph.D.
William Henry Newman, Dr.Ing.
Gilberto Russo, Ph.D.
Ziaedin Vafa, Ph.D.
Guillermo Weber, Ph.D.

Research Affiliates

Joseph Seaton Barr, Jr., M.D.
Donald Lee Grimes, Ph.D.
Lindsay Russell, S.M.

Professors Emeriti

Nathan Henry Cook, Sc.D.
Professor of Mechanical Engineering, Emeritus

Jacob Pieter Den Hartog, Ph.D., D.Eng., D.Appl.Sc., D.Tech.Sc., D.Sc. (honoris causa)
Professor of Mechanical Engineering, Emeritus

Shih-Ying Lee, Sc.D.
Professor of Mechanical Engineering, Emeritus

William MacGregor Murray, Sc.D.
Professor of Mechanical Engineering, Emeritus

Egon Orowan, D.Eng.
Professor of Mechanical Engineering, Emeritus

Henry Martyn Paynter, Sc.D.
Professor of Mechanical Engineering, Emeritus

Augustus Rudolph Rogowski, S.M.
Professor of Mechanical Engineering, Emeritus

Warren Max Rohsenow, D.Eng.
Professor of Mechanical Engineering, Emeritus

Ascher Herman Shapiro, Sc.D.
Institute Professor, Emeritus

Prescott A. Smith, S.B.
Professor of Mechanical Engineering, Emeritus

Charles Fayette Taylor, Ph.D., M.E.
Professor of Automotive Engineering, Emeritus

Tau-Yi Toong, Sc.D.
Professor of Mechanical Engineering, Emeritus

Kenneth Wadleigh, Sc.D.
Professor of Mechanical Engineering, Emeritus

Department of Mechanical Engineering

(Course 2)

Engineering is a creative profession concerned with combining human, material, and economic resources to satisfy the needs of society. Mechanical engineering is one of the broadest and most versatile of the engineering professions.

The educational program in mechanical engineering prepares students for professional practice in an era of rapidly advancing technology. It combines a strong base in the engineering sciences (mechanics and materials, fluid and thermal sciences, and systems and control) with project-based laboratory and design experience. It strives to develop independence, creative talent, and leadership as well as the capability for continuing professional growth.

Several broad areas of professional concentration described below are illustrative of the rewarding career opportunities for mechanical engineering graduates in the years ahead:

Energy Conversion and Conservation. This area includes the technology associated with the design, construction, and operation of equipment for energy conversion and conservation, especially the conversion of thermal, nuclear, chemical, mechanical, and electrical energy. New concepts in turbines, generators, boilers, and internal combustion engines, as well as heat pumps, fuel cells, thermionic converters, and solar heating systems are of interest.

Given the importance of energy supply, this field is fundamental to our economy. Mechanical engineering provides a broad background for a career in almost all aspects of the power and energy industries.

Environmental Engineering. The approach to environmental problems reflects the dual goals of halting environmental degradation and of designing technologies for conserving limited material and energy resources. Examples include modeling the transport of pollutants in air and in water; increasing water supplies by desalinating salt water and by purifying waste waters; recycling solid wastes; increasing the durability of capital and consumer goods; controlling the ecological impacts of thermochemical pollutants; regulating thermal pollution by upgrading the heat-transfer technology of cooling towers; improving food supplies by exploiting the potentials of sewage and thermal wastes; and reducing the levels of toxic chemicals emitted from automobiles, aircraft, and various industrial facilities.

These diverse activities in the Department share a common commitment to reducing environmental hazards while converting potential liabilities into material and energetic assets. This commitment demands an understanding of physical, chemical, and biological aspects as well as of ecological processes.

Biomedical Engineering. There is a growing recognition of the enormous potential of science and engineering for the advancement of human health. This includes deeper understandings of physiology, advanced methods of medical diagnosis and therapy, more effective and economical health care systems, and the development of devices concerned with all the foregoing.

An undergraduate foundation in engineering can be directed either toward a career as a biomedical engineer, or toward medical school and practice and research in medicine. The Department of Mechanical Engineering, with its course offerings in biomedical engineering and its extensive research programs in medically related topics, provides an excellent undergraduate base for either of these directions. Ample opportunity exists, through project laboratories and thesis, for engineering-based medical research and/or clinical experience.

Manufacturing and Materials Processing. Mechanical engineers have a strong interest in the production of equipment, components, and materials. The manufacturing industry comprises a major element of the economy, and its productivity strongly influences domestic living standards and competitive positions in international trade.

Industrial production encompasses a range of subject areas from pure research to technical management, including physics of manufacturing processes; design and control of manufacturing processes and machinery; design, implementation, and operation of complex manufacturing systems; and optimization of processes and products relative to societal needs. This field includes computer-controlled automation of complete manufacturing systems, and robotics.

Mechanics and Materials. More than ever, new concepts in designs, the use of new materials, plus the economic need to conserve materials are challenging the ingenuity and resourcefulness of today's engineers in the area of mechanics and materials. A disciplinary program in mechanics and materials has many diverse applications, and may include courses on the static and dynamic behavior of structures, acoustics, the mechanics of continua, the mechanical behavior of conventional and newly established engineering materials, and modern methods of computational mechanics to analyze solids and structures.

Mechanical Engineering Design. Design, in the engineering sense of deliberate creation of something new and useful, is at the heart of most of the diverse fields in mechanical engineering. Design in itself can be rewarding, and core courses provide the broad background upon which advanced design courses in specific disciplinary fields are built. Undergraduate and graduate experience includes courses ranging from introduction to design, through machine elements, design projects, and computer-aided design, to advanced design projects offering an opportunity to develop prototype equipment. Several thesis topics each year are strongly oriented toward design, with ample opportunity to conceive, design, build, and test innovative solutions to "real world" problems.

Transportation. The transportation of people and goods vitally affects the economy and the quality of life. The growing need for better transportation services coupled with increasing emphasis on safety, environmental protection, and energy conservation creates many new and satisfying opportunities for mechanical engineering graduates to contribute to this important field. Mechanical engineering encompasses the basic technologies of transportation, including structures (vehicles, guideways, and terminals), power and propulsion, and automation and control. The core program provides a sound background for entering almost any of the many transportation fields, but particularly those related to ground transportation.

Systems, Computers, and Control. This field centers around the methodology for the analytical modeling, computer simulation, and control of all types of engineering systems. It includes the application of computers to engineering analysis, optimization, and design, and the use of feedback techniques and associated hardware to automate or control physical devices or processes. The low-cost microprocessor is already revolutionizing the design of devices in such developing fields as automated manufacturing, power generation, energy conservation, transportation, pollution control, and health care.

Mechanical engineering provides the strong engineering-science base needed for professional work in this field combined with a range of basic and applied courses and laboratories in automatic control, system dynamics, computers, and computer hardware design. Educational opportunities are enhanced by local computer facilities which allow students "hands-on" experience in digital, analog, and hybrid computers along with interactive graphics.

Undergraduate Study

Research Laboratories and Programs

The Department is organized into three divisions: Mechanics and Materials, Thermal and Fluid Sciences, and Systems and Design, and has active research programs at the forefront of a wide range of fields in these areas.

The educational opportunities afforded students in mechanical engineering are enhanced by the availability of a wide variety of research laboratories and programs, and well-equipped shops and computer facilities.

Many are interdepartmental laboratories and centers, described in detail in Chapter VI:

Center for Transportation Studies
Energy Laboratory
Innovation Center
Laboratory for Manufacturing and Productivity
Mining and Mineral Resources Research Institute

Among the more important Departmental laboratories, and their major areas of research, are:

Acoustics and Vibrations Laboratory — vibration and acoustical studies applied to a diverse range of problem areas.

Eric P. and Evelyn E. Newman Laboratory for Biomechanics and Human Rehabilitation — technology appropriate to human rehabilitation, including development of artificial limbs and hip implants, basic studies of human mobility, and aids to the blind.

Reacting Gas Dynamics Laboratory — fluid flow, chemical reactions, and excitation processes occurring in the fields of power generation and energy conversion.

Combustion and Propulsion Laboratory — combustion-fluid mechanics problems arising from fire, explosion hazards, and energy conversion.

Cryogenic Engineering Laboratory — superconducting electric generator and the application of thermodynamics and heat transfer to cryogenic refrigeration.

Fibers and Polymers Laboratories — fiber physics, textile processing dynamics, polymer engineering, and the development of biological materials such as artificial skin.

Fluid Mechanics Laboratory — fundamental research in computational fluid mechanics, physicochemical flows, turbulent transport and dispersion, multiphase flows and phase change; applications in biomedical systems, augmented heat transfer, slurry transport, atmospheric dispersion and the acid rain problem, toxic wastes in ground waters, etc.

Heat Transfer Laboratory — heat transfer and cooling in a variety of applications, including electronic devices, nuclear power, thermal modeling of biological tissue, and moisture migration in building materials.

Man-Machine Systems Laboratory — interactions between people and the systems which they control.

Machine Dynamics Laboratory — studies the dynamics of high-speed mechanisms, machines and control systems, and the use of dynamical response data for operational diagnostics.

Mechanical Behavior of Materials Laboratory — mechanisms of deformation and fracture processes in engineering materials.

Laboratory for Medical Ultrasonics — application of ultrasonic radiation to surgery, diagnosis, and to the treatment of tumors through hyperthermia.

Sloan Automotive Laboratory — fundamental combustion studies, internal combustion engine research, gas turbine and burner research, and policy and technology studies.

Surface Laboratory — various aspects of tribology, including high-speed friction, wear theory, lubrication, friction and adhesion, magnetic recording and sliding electric contacts.

Vehicle Dynamics Laboratory — improving the dynamic performance characteristics of ground transport vehicles and their guideways with specific attention directed to dynamic performance, safety, ride quality, handling, and cost.

The undergraduate program provides a broad intellectual foundation. A firm technical background is essential for a career as diversified and challenging as that open to the mechanical engineer. Beginning with mathematics, physics, and chemistry, students acquire proficiency in the engineering sciences: dynamics, mechanics, and properties of materials; fluid dynamics; heat and mass transport; thermodynamics; systems analysis; and control. Further, students experience the ways in which scientific knowledge can be put to use in the development and design of useful devices and processes to solve engineering problems. Mastery of this art, largely by project-oriented work of a creative nature, is the primary object of subjects in laboratory and design. Design experience often involves consideration of economic, social, legal, and political factors.

Bachelor of Science in Mechanical Engineering
Course II

The Department provides many opportunities for undergraduates to establish a close relationship with faculty members and their research groups in the Department. Students interested in project work may consult their faculty advisors or approach other members of the faculty.

The curriculum for the Bachelor of Science in Mechanical Engineering has been designed to provide alternatives — through the Restricted and Unrestricted Electives — for students having a wide range of career goals. The Department recognizes in its curriculum three categories of students it wishes to serve: 1) those who base their professional careers as mechanical engineers on the bachelor's degree with no further formal study; 2) those who proceed to formal graduate study in mechanical engineering or in an allied field; and 3) those for whom the undergraduate program provides a broad base — in intellectual style as well as intellectual content — for further professional study directed toward medicine, law, business, or industrial management.

The departmental requirements provide a balanced background in mechanical engineering while allowing students who defer entering the Department until the end of the second year to graduate in the normal four-year period. (The latter assumes that students have met the General Institute Science Requirements and have taken 18.03 Differential Equations.) This program is accredited by the Accreditation Board for Engineering and Technology.[1]

[1] See discussion of significance of accreditation under "Degree Programs in Engineering" in the Dean's statement at the beginning of the School of Engineering section.

The departmental program for the Bachelor of Science in Mechanical Engineering, Course II, consists of three levels corresponding roughly to the second, third, and fourth years. The first and second levels constitute the universal core of subjects required of all candidates for the S.B. in Mechanical Engineering.

The first level provides a fundamental introduction to mechanical engineering through courses in system dynamics, solid mechanics, manufacturing and materials processing, instrumentation, and design. The second level emphasizes the basic engineering sciences and their integration through laboratory and design projects. The third level consists of professional electives and leads into areas of professional concentration, either in the engineering sciences, Group A; or the broader aspects of engineering systems and design, Group B. In the former category students interested in the technology of fields such as bioengineering, pollution, energy, materials, and automatic control may select additional courses from other engineering departments and the School of Science. Some students may place more emphasis on the humanities and social sciences, as preparation for graduate study in such fields as engineering of social systems, technology and policy, law, management, technology assessment, and medicine. All students are required to complete a thesis, working on an individual basis with a faculty or research-staff member.

Students are urged to contact the Undergraduate Office as soon as they have decided to enter mechanical engineering so that faculty advisors may be assigned. Students together with their faculty advisors plan a program that best utilizes the two (24 units) Restricted Electives and the 51 units of Unrestricted Electives available in the Course II degree program. Although the selection of elective courses is an individual decision, the faculty of the Department has developed areas of professional concentration in Power and Energy, Environmental Engineering, Manufacturing and Materials Processing, Biomedical Engineering, and Computers and Control. The detailed programs and suggested electives are available from the Undergraduate Office. These fields are not all-inclusive; students interested in other professional programs — including interdisciplinary programs — should consult their faculty advisor or the Department Head.

Bachelor of Science in Mechanical Engineering Course II

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 2.01, 2.02, or 2.40 and by 18.03 in the Departmental Program][1]	3
The Laboratory Requirement [can be satisfied by any combination of the subjects 2.671, 2.672, and 2.86 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program[2]	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	141
2.01[3] Mechanics of Solids, 12; 8.01, 18.02	
2.02[3] Introduction to Systems Dynamics, 12; 8.01, 18.02	
2.03J Dynamics, 12; *2.01*, 2.02, 18.03	
2.20[3] Fluid Mechanics, 12; 18.02, *18.03*	
2.30 Mechanical Behavior of Materials, 15; 2.01, 2.671, *2.86*	
2.40[3] Thermodynamics, 12; 8.02, *18.03*	
2.671[3] Measurement and Instrumentation, 12, *2.02*	
2.672 Project Laboratory, 6; *2.20*, 2.40, 2.671	
2.70[3] Introduction to Design, 9	
2.73 Design Projects, 9; *2.03J*, 2.20, 2.30, 2.40, 2.70	
2.86 Manufacturing Processes and Systems, 9	
18.03[3] Differential Equations, 12; 18.02**	
Thesis[4] (9 units)	
Restricted Electives:	24
Two of the following ten subjects, at least one from Group A; additional subjects taken may be used for G (non-A) credit toward graduate degrees in mechanical engineering.	
Group A	
2.06J Mechanical Vibration, 12; 2.03J**	
2.14 Control System Principles, 12; 2.02	
2.22 Computational Methods in Engineering, 12; 18.03, 2.10	
2.34J The Mechanics of Fracture, 12; 2.30	
2.41J Thermodynamics of Power Systems, 12; 2.40	
2.51 Heat and Mass Transfer, 12; 2.20, 2.40	
Restricted Electives (continued)	
Group B	
2.72 Elements of Mechanical Design, 12; 2.01, 2.70	
2.96 Management in Engineering, 12	
14.01[5] Principles of Microeconomics, 9	
14.02[5] Principles of Macroeconomics, 9	
Units in Departmental Program that also satisfy the General Institute Requirements	(36)
Unrestricted Electives[6]	51
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Bachelor of Science Course II-A

Many students have a defined goal that can best be met by organizing a curriculum specifically tailored to that goal. To meet such needs, the Department offers the Bachelor of Science, with a significant part of the curriculum made up of Planned Electives. These are chosen by agreement between the student and a departmental officer so that the complete curriculum is coherent and in pursuit of a clear objective.

For instance, some students may wish to go more deeply into some field of mechanical engineering by choosing additional courses in one of the professional fields of concentration already mentioned, as well as introductory graduate courses from among the related engineering sciences. Others interested in electromechanical devices might combine advanced courses in dynamics, systems analysis, and vibrations with courses in electric circuits and electromagnetic field theory. Students interested in air pollution, fires, internal-combustion engines, and related fields involving chemical reaction might make up a package involving work in fluid mechanics, heat transfer, physical chemistry, reaction kinetics, and statistical mechanics. Some combine subjects in mechanical engineering with subjects in economics and management. Students interested either in medical school or in a career in biomedical engineering may wish to develop backgrounds in biology, biochemistry, or physiology. Many other combinations are possible.

1
The Department suggests that 6.071 Introduction to Electronics be elected.

2
Substitution of subjects of similar content may be permitted by petition to the senior registration officer. Certain graduate subjects may be substituted for restricted electives with permission of the senior registration officer.

3
Students must receive a grade of C or better in these core subjects (which serve as prerequisites for other departmental core subjects) before continuing in the departmental program.

4
To foster substantial research and design achievement, the Department permits up to 6 units of additional thesis credit, subject to approval of the student's faculty advisor.

5
Students must take *both* 14.01 and 14.02 to receive credit for *one* restricted elective.

6
The Department recommends that students elect an introductory digital-computing subject (such as 2.10) as early as possible in their programs.

Students who wish to pursue this degree must advise the Department's Undergraduate Officer by the beginning of their junior year in order that there be adequate opportunity for planning the complete curriculum. Registration for this degree program requires approval in writing from the Registration Officer in charge of Course II-A. This program leading to the undesignated Bachelor of Science is not accredited by the Accreditation Board for Engineering and Technology, and students should discuss the significance of this with their faculty advisor.

The Course II-A curriculum is similar to Course II. Course II-A is substantially more flexible in that, in addition to thesis, students need to take 90 units from among the lists of Required Subjects and Restricted Electives shown under Course II. The remainder of the program is Planned Electives (consisting of six subjects), aimed at a well-defined educational goal, and Unrestricted Electives, for a total program beyond the General Institute Requirement of 180 units. Further details may be obtained from the Department.

Engineering Internship Program in Mechanical Engineering Course II-B

Students who wish to gain industrial experience during their undergraduate and graduate programs may do so by electing to participate in the Engineering Internship Program, described in detail in the School of Engineering section, through enrollment in Course II-B.

The Course degrees and curricular requirements are the same as for Course II; however, in addition, provision is made for the students to be employed at the cooperating companies. The plant work at the undergraduate level consists of two summers, starting with the summer after the sophomore year. The plant work is considered as equivalent to a 12-unit elective subject: 2.951 Engineering Internship. This program is accredited by the Accreditation Board for Engineering and Technology.

Students in this program interested in graduate study are encouraged to apply for early graduate-school admission under the combined Bachelor's and Master's program (See the following section). A student in this Program may spend an additional seven months (one summer and one term) at the cooperating company and write a single combined bachelor's and master's thesis. Subject to approval of the thesis supervisor, the thesis may be related to the work experience.

Additional information may be obtained from Professor Igor Paul, Room 3-461B, MIT, Cambridge, Massachusetts 02139, (617) 253-4466.

Double Major (Second S.B. Degree in Mechanical Engineering)

Undergraduates enrolled in other MIT departments may also earn the S.B. in Mechanical Engineering by satisfying the previously described Departmental requirements and completing a minimum of 90 units, acceptable to the Department, beyond the units required for the first S.B. Degree. If an S.B. thesis is completed in another MIT department, the Mechanical Engineering thesis requirement is waived. Further details may be obtained from the Department.

Some students may wish to combine a professional education in Mechanical Engineering with a liberal education that links the development and practice of engineering with its social, economic, historical, and cultural contexts. For them, the Department of Mechanical Engineering and the Department of Humanities, in cooperation with the Program in Science, Technology, and Society, offer a double-degree program that combines majors in Course II and in Course XXI. A detailed description of that integrated program will be found under the Program in Science, Technology, and Society.

Inquiries

Further information on undergraduate programs, admissions, and financial aid may be obtained from Professor David Gordon Wilson or Professor Peter Griffith, Room 3-154, MIT, Cambridge, Massachusetts 02139, (617) 253-2305.

Combined Bachelor's and Master's Degree Program

Some students who obtain early admission to the graduate program may be permitted to delay satisfying all of the Bachelor's degree requirements until their fifth year, satisfying the requirements for both degrees simultaneously. This program permits students to complete some basic core graduate subjects in their senior year, leaving time to take more advanced subjects during the graduate year. With prior approval in their fourth year, students in this program may combine the work of the Bachelor's and Master's theses into a single thesis of scope comparable to both theses. The Master's study may be within the Department or in a cooperating department such as Nuclear Engineering. Students interested in these programs should consult the chairman of the departmental graduate committee early in the senior year.

Bachelor of Science in Mechanical Engineering Course II

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
The Science Distribution Requirement can be satisfied by 2.01, 2.02, 2.20, or 2.40 and by 18.03 in the Departmental Program, plus appropriate subjects totaling[1]	12
The Laboratory Requirement can be satisfied by any combination of the subjects 2.671, 2.672, and 2.86 in the Departmental Program.	

Departmental Program[2]

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 141

2.01	Mechanics of Solids, 12; 8.01, 18.02
2.02	Introduction to Systems Dynamics, 12; 8.01, 18.02
2.03J	Dynamics, 12; *2.01*, 2.02, 18.03
2.20	Fluid Mechanics, 12; 18.02, *18.03*
2.30	Mechanical Behavior of Materials 15; 2.01, 2.671, *2.86*
2.40	Thermodynamics, 12; 8.02, *18.03*
2.671	Measurement and Instrumentation, 12, *2.02*
2.672	Project Laboratory, 6; *2.20*, 2.40, 2.671
2.70	Introduction to Design, 9
2.73	Design Projects, 9; *2.03J*, 2.20, 2.30, 2.40, 2.70
2.86	Manufacturing Processes and Systems, 9
18.03	Differential Equations, 12; 18.02*
	Thesis[3] (9 units)

Restricted Electives: 24

Two of the following ten subjects, at least one from Group A; additional subjects taken may be used for G (non-A) credit toward graduate degrees in mechanical engineering.

1 The Department suggests that 6.071 Introduction to Electronics be elected.

2 Substitution of subjects of similar content may be permitted by petition to the senior registration officer. Certain graduate subjects may be substituted for restricted electives with permission of the senior registration officer.

3 To foster substantial research and design achievement, the Department permits up to 6 units of additional thesis credit, subject to approval of the student's faculty advisor.

Restricted Electives (continued)

Group A

2.06J	Mechanical Vibration, 12; 2.03J*
2.14	Control System Principles, 12; 2.02
2.22	Computational Methods in Engineering, 12; 18.03, 2.10
2.34J	The Mechanics of Fracture, 12; 2.30
2.41J	Thermodynamics of Power Systems, 12; 2.40
2.51	Heat and Mass Transfer, 12; 2.20, 2.40

Group B

2.72	Elements of Mechanical Design, 12; 2.01, 2.70
2.96	Management in Engineering, 12
15.001[4]	Managerial Economics, 12

Unrestricted Electives 51

[The Department recommends that students elect an introductory digital-computing subject (such as 2.10) as early as possible in their programs.]

Total Units Required for the S.B. Degree 360

*Alternate prerequisites are listed in the subject description.

Graduate Study

The Mechanical Engineering Department provides opportunities for graduate work leading to the following degrees: Master of Science in Mechanical Engineering, Master of Science without specification of department, the Mechanical Engineer's degree, and the Doctor of Philosophy (Ph.D.) or Doctor of Science (Sc.D.), which differ in name only.

Most students who come for the Master's degree take the degree with specification in Mechanical Engineering. There are always some, however, who prefer to forego the specification in order to allow themselves more freedom in the selection of courses. The two Master's degrees have equal academic stature.

The Engineer's degree offers preparation for a career in advanced engineering practice. It does so through a program of advanced coursework that goes well beyond the Master's level. This degree is normally not used as a stepping stone toward the Ph.D.

The Doctor of Philosophy (or Science) is the highest academic degree offered. It is awarded upon the completion of a program of advanced study and significant original research, design, or development.

Entrance Requirements for Graduate Study

Applications to the Mechanical Engineering Graduate School are accepted from persons who have completed, or will have completed by the time they arrive, a Bachelor's degree. Most incoming students have a degree in Mechanical Engineering or some related branch of engineering. The Department's admission criteria are not specific, however, and capable students with backgrounds in different branches of engineering or in science may gain entry. However, to qualify for a graduate degree other than the Master's without specification, the candidate is expected to have had at least an undergraduate-level exposure to the core ME subject areas (applied mechanics, dynamics, fluid mechanics, thermodynamics, materials, and design) and to be familiar with basic electric circuits and electromagnetic field theory. Those with deficiencies may be asked to make up courses in certain areas before they graduate.

Applications for September entry are due on January 15 of the same year, and decisions are reported in March. Applications are also accepted for February (second term) entry; these are due on November 15 of the previous year, and decisions are reported in December. Foreign students applying from abroad are admitted only if they have full financial support for the first year.

The GRE (Graduate Record Examination) is not required for domestic students, though it is recommended that students applying from abroad take it and submit their scores. Students applying from non-English-speaking countries are required to take the TOEFL test (Test of English as a Foreign Language) and receive a score higher than 575.

Writing Ability Requirement

The Mechanical Engineering Department requires that all incoming graduate students demonstrate satisfactory English writing ability, or successfully complete appropriate training in writing. This requirement reflects the faculty's conviction that writing is an essential skill for all engineers. All incoming graduate students, native as well as foreign, must take the departmental writing ability test, which is administered in September. Depending on the results, a student will either pass or be required to take a course in writing.

Master of Science in Mechanical Engineering

To qualify for the Master of Science in Mechanical Engineering, a student must complete at least 66 credits of coursework (about six courses). Of these, at least 42 must be "A-level" graduate subjects, designated by the letter A next to their titles in Chapter VIII. The rest of the 66 units may be for "G-level" subjects or advanced undergraduate subjects that are not requirements in the undergraduate Mechanical Engineering curriculum.

At least two of the subjects must be chosen from a prescribed list of basic Mechanical Engineering sciences, and the student must also either have had previously, or take as part of his Master's program, two advanced mathematics subjects (e.g., 18.075 and 18.076, or 18.085 and 18.086).

Finally, a thesis is required. The thesis is an original work of research, development, or design, performed under the supervision of a faculty or a research staff member, and is a major part of any graduate program at MIT. A Master's student usually spends as much time on thesis work as on coursework. Details of the program are available from the Departmental Graduate Office. A Master's degree usually takes about 1.5 years to complete.

[4] Students may take *both* 14.01 and 14.02 to receive credit for *one* restricted elective in place of 15.001.

Master of Science in the Management of Technology

Individuals who would like to apply their mechanical engineering background and at least five years of technical work experience to issues in technical management may want to explore the Program in the Management of Technology. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, this program entails a rigorous twelve-month curriculum, focusing on management principles for technical people in a technical environment. The program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program and application procedures are described in Chapter VI.

Master of Science (without Specification)

The requirements for the Master of Science without specification are that the student take 66 credit units of subjects, with 42 of them being A level, and the completion of a thesis. These are the minimum requirements for an M.S. degree at MIT. The degree without specification and the one with specification have equal academic stature. The degree without specification does not, however, explicitly confer an association with the Mechanical Engineering profession, though such an association may be inferred from the student's having been registered in the Mechanical Engineering Department. Students who opt for the degree without specification usually have in mind specific programs of study with which they cannot meet all the M.S.M.E. degree requirements in the time they have available.

Mechanical Engineer's Degree

The Mechanical Engineers's degree provides an opportunity for further study beyond the Master's level for those who wish to enter engineering practice rather than research. This degree emphasizes breadth of knowledge in Mechanical Engineering and its economic and social implications, and is quite distinct from the Ph.D., which emphasizes depth and originality of research.

The Engineer's degree requires a broad program of advanced coursework in Mechanical Engineering and management, totaling at least 162 credit units (typically about 14 courses), including those taken during the Master's degree program. The program is centered around the application of engineering principles to advanced engineering problems and includes an applications-oriented thesis, which may be an extension of a suitable Master's thesis. Details of the program may be obtained from the Departmental Graduate Office. An Engineers's degree typically requires at least one year of study beyond the Master's degree.

Doctor of Philosophy and Doctor of Science

The highest academic degree is the Doctor of Science, or Doctor of Philosophy (the two differ only in name). This degree is awarded upon the completion of a program of advanced study, principally at the Institute, and the performance of significant original research, design, or development.

Students become candidates for the doctorate by passing a rigorous qualifying examination, which they take no later than at the end of three regular terms after arrival or after the completion of the Master's degree. The doctoral program includes a major program of advanced study in the student's principal area of interest, and a minor program of study in a different field.

The principal component of the program is the thesis. The thesis is a major, original work that makes a significant research, development, or design contribution in its field. The thesis and the program of study are done under a faculty supervisor and a doctoral committee selected by the student and his supervisor, and perhaps other interested faculty members. The committee makes an annual examination of the candidate's progress and conducts a final examination based on the thesis. The doctoral program usually takes a minimum of two years of work beyond the Master's degree.

Interdisciplinary Programs

Graduate students registered in the Mechanical Engineering Department may elect to participate in interdisciplinary programs of study. Programs are available in health sciences and technology, polymer science and technology, technology and policy, etc. There is also a joint program between MIT and Woods Hole Oceanographic Institute for students whose primary career objective is oceanographic engineering. Furthur information is available from the Departmental Graduate Office.

Assistantships and Fellowships

The Department of Mechanical Engineering offers three types of financial assistance to graduate students: Fellowships, Research Assistantships, and Teaching Assistantships.

A Fellowship provides the student with a direct grant, and leaves the student open to select his or her own research project and supervisor. A number of students in the Department are supported by fellowships from outside agencies. The Department itself has very few fellowships to offer, however.

The majority of students in the Department are supported by Research Assistantships, which are appointments to work on particular research projects with particular faculty members. The faculty members procure research grants for various projects and hire graduate students to carry out the research. The research is almost invariably structured so that it becomes the student's thesis. An RA appointment provides a full tuition scholarship (i.e., covers all tuition) plus a salary that is adequate for a single person. The financial details are outlined in a separate handout available from the Departmental Graduate Office. An RA may register for a maximum of 24 units (about two subjects) of classroom subjects per regular term and 12 units in the summer term, and must do at least the equivalent of 24 units of thesis (i.e., research on the project) per term.

Teaching assistants are appointed to work on specific subjects of instruction. As the name implies, they usually assist a faculty member in teaching, often grading homework problems and tutoring students. In the Mechanical Engineering Department, TAs are very seldom used for regular full-time classroom teaching. TAs are limited to 24 units of credit per regular term, including both classroom subjects and thesis. The TA appointment does not usually extend through the summer.

Experience has shown that the optimum graduate program consists of about equal measures of coursework and research, consistent with an RA appointment. The main advantage of a fellowhip is a greater freedom in choosing a research project and supervisor. A Teaching Assistantship gives the student teaching experience and can also be extremely valuable for reviewing basic subject material, for example in preparation for the doctoral general exams. It does not, however, leave much time for thesis research, and may extend the time that the student needs to complete his degree.

Inquiries

Additional information concerning the details of the academic and research programs, admissions, financial aid, etc., may be obtained by writing to Ms. Leslie Regan, Mechanical Engineering Graduate Registration Office, Room 1-106, MIT, Cambridge, Massachusetts 02139, (617) 253-2291.

Department of Nuclear Engineering

(Course 22)

Neil Emmanuel Todreas, Sc.D.
Professor of Nuclear Engineering
Head of the Department

Professors

Gordon Lee Brownell, Ph.D.
Professor of Nuclear Engineering

Sow-Hsin Chen, Ph.D.
Professor of Nuclear Engineering

Michael John Driscoll, Sc.D.
Professor of Nuclear Engineering

Thomas Henderson Dupree, Ph.D.
Professor of Nuclear Engineering and Physics

Jeffrey Philip Freidberg, Ph.D.
Professor of Nuclear Engineering

Michael Warren Golay, Ph.D.
Professor of Nuclear Engineering

Elias Panayiotis Gyftopoulos, Sc.D.
Ford Professor of Engineering
Professor of Nuclear and Mechanical Engineering

Kent Forrest Hansen, Sc.D.
Professor of Nuclear Engineering
Associate Director, Energy Laboratory

Otto Karl Harling, Ph.D.
Professor of Nuclear Engineering
Director, MIT Nuclear Reactor Laboratory

Allan Francis Henry, Ph.D.
Professor of Nuclear Engineering

Mujid Suliman Kazimi, Ph.D.
Professor of Nuclear Engineering

David Dayton Lanning, Ph.D.
Professor of Nuclear Engineering

Lawrence Mark Lidsky, Ph.D.
Professor of Nuclear Engineering

John Edward Meyer, Ph.D.
Professor of Nuclear Engineering

Norman Carl Rasmussen, Ph.D.
McAfee Professor of Engineering
Professor of Nuclear Engineering

Kenneth Calvin Russell, Ph.D.
Professor of Nuclear Engineering and Metallurgy

Sidney Yip, Ph.D.
Professor of Nuclear Engineering

Associate Professors

Ronald George Ballinger, Sc.D.
Associate Professor of Nuclear and Materials Science and Engineering

Ian Horner Hutchinson, Ph.D.
Associate Professor of Nuclear Engineering
Head, Alcator Group, Plasma Fusion Center

Richard Keith Lester, Ph.D.
Associate Professor of Nuclear Engineering

Kim Molvig, Ph.D.
Associate Professor of Nuclear Engineering

Assistant Professor

Nathan Siu, Ph.D.
Assistant Professor of Nuclear Engineering

Senior Lecturer

Francis X. Masse, B.S.
Radiation Protection Officer, Medical Department

Administrative Officer

Jennifer deVries Gwinn

Administrative Assistant

Clare Marie Egan

Research Staff

Rachel M. Morton, B.S.
Manager, Computer Facilities

Senior Research Engineers

D. Bruce Montgomery, Sc.D.
Associate Director, Plasma Fusion Center
Senior Research Engineer, Plasma Fusion Center and Nuclear Engineering

John E. C. Williams, B.Sc.
Senior Research Engineer, Francis Bitter National Magnet Laboratory and Nuclear Engineering

Senior Research Scientists

Daniel R. Cohn, Ph.D.
Senior Research Scientist, Plasma Fusion Center and Nuclear Engineering

Marvin M. Miller, Ph.D.
Senior Research Scientist, Nuclear Engineering and Center for International Studies

Research Scientist

Dieter J. Sigmar, Ph.D.
Research Scientist, Plasma Fusion Center and Adjunct Professor of Nuclear Engineering

Research Affiliates

Ronald Christensen, Ph.D.
Vincent Manno, Sc.D.
Andrei Schor, Ph.D.
Kord Smith, Ph.D.
William E. Vesely, Ph.D.
Lothar Wolf, Ph.D.

Professors Emeriti

Manson Benedict, Ph.D.
Institute Professor, Emeritus
Professor of Nuclear Engineering, Emeritus

Irving Kaplan, Ph.D.
Professor of Nuclear Engineering, Emeritus

Department of Nuclear Engineering

(Course 22)

The Department of Nuclear Engineering provides undergraduate and graduate education for students interested in developing the peaceful applications of nuclear reactions, plasma physics, and radiation. In keeping with MIT's traditional role in other branches of knowledge, the Department aims to educate the individuals who make the key scientific and engineering advances in these fields. The technological problems of energy generation by neutron-induced fission of heavy elements in nuclear reactors and fusion of light particles in thermonuclear plasmas receive primary emphasis.

In addition, faculty and students are strongly involved in the engineering physics of charged particles, neutrons, and photon radiation; in the broader problems of providing energy in socially acceptable ways; in the medical applications of radiation; and in radiation health physics.

Fission reactors are used to generate heat and electricity, to propel submarines and ships, to transmute elements, and to produce radioisotopes for medical and other applications. In some countries, the fraction of electricity obtained from nuclear power is greater than 50 percent. In the United States it is about 15 percent. In recent years, the growth rate of electricity has declined because of more cost-effective uses of energy and the international economic recession. This has led to a significant reduction in new nuclear power plant orders. Nevertheless, many nations include a significant and expanding nuclear component in their energy programs because they are convinced that nuclear power is a comparatively reliable, inexpensive, and safe way to produce electricity.

The safe and economic development, design, construction, and operation of nuclear power plants and their related nuclear fuel processing facilities is a major field of engineering. Challenging tasks facing today's nuclear engineers are to reduce the capital cost of nuclear power stations, to increase their reliability, and to extend the life of nuclear fuels so that nuclear plants can be the most economic way of generating electricity in ever-widening regions of the world.

Another challenge to nuclear engineers is the development of economic nuclear power systems that regenerate or yield a net increase in their essential fuel, such as breeder reactors. Breeder reactors can provide an energy resource capable of supplying the needs of the world for thousands of years.

A potential source of energy and neutrons is controlled fusion of light elements. Energy from fusion would be practically inexhaustible. Fusion reactions must be carried out in a fully ionized plasma heated to many million degrees. Such plasmas are usually confined by strong magnetic fields. Recent progress increases the likelihood that controlled fusion will become a practical source of energy and neutrons within the lifetime of today's engineering students. Attainment of a fusion power plant requires improved behavior of plasmas in electric and magnetic fields, development of materials capable of withstanding high stresses and exposure to intense radiation, and great engineering ingenuity in combining fusion power components into a practical and economic system. The Department has strong programs in plasma fundamentals, materials for intense radiation fields, and engineering of fusion systems.

The fundamentals of plasmas also underlie astrophysical and ionospheric phenomena, magnetohydrodynamic energy conversion, ion propulsion, thermionic energy conversion, and high-power gas lasers, all topics of interest in the Department. Students concentrating on applied plasma physics are therefore trained not only to contribute to the advancement of controlled fusion but also to apply their knowledge in areas of immediate practical significance. In these plasma programs, the Department is an active participant in MIT's broad, interdepartmental program of research and instruction in plasma physics and its varied applications.

To achieve the full potential of nuclear energy from either fission or fusion reactors, it is necessary to develop special materials capable of withstanding intense radiation for long periods of time. The Department's nuclear materials engineering program is concerned with effects of radiation on materials and development of improved radiation-resistant materials. Other areas of concentration are the chemical and metallurgical engineering aspects of the production and fabrication of fuels for fission reactors, the processes for recovering these materials from the highly radioactive spent fuel discharged from reactors, and processing and enrichment of fuels for fusion reactors.

To fulfill society's needs, not only must new technologies be developed, but energy conversion plants must also be designed and operated so as to produce energy safely, reliably, economically, and with acceptable environmental impact. Consequently, the Department is involved actively across the entire field of energy production in the areas of thermal-hydraulics, structural mechanics, reliability analysis, safety and licensing, health physics, environmental impact of power production, and engineering economics.

The Department's radiation science and technology program is devoted to studying the production and uses of neutrons, charged particles, gamma rays, light and other radiations from fission reactors, radioisotopes, particle accelerators, and lasers. Topics treated include the detection and measurement of radiation, the interaction of radiation with matter, the use of radiation in processing materials, the design of irradiators, biological effects of radiation, and the use of scattering experiments with neutrons and coherent light to determine the structure and molecular dynamics of solids, liquids, and dense gases. In particular, the program of radiological sciences encompasses medical applications of radiations for therapy, diagnostics, and radiobiology. It includes not only nuclear radiations but also ultrasound, laser light, and nuclear magnetic resonance interactions.

The radiation health physics program is designed to provide students with a strong foundation in the scientific and engineering disciplines needed for the management and control of irradiation exposures. It emphasizes principles of radiobiology, radiation measurement and dosimetry, risk assessment, and management of radiation exposure.

In all the programs, attention is focused on the related aspects of science and engineering — for example, low-energy nuclear physics, plasma physics, nuclear materials, high-flux heat transfer, and numerical methods. The approach is interdisciplinary and draws heavily upon important segments of physics, chemistry, applied mathematics, and metallurgy, and on the techniques of chemical, civil, electrical, and mechanical engineering.

Undergraduates and graduate students in other departments at MIT who wish to learn how their major professional fields may be utilized in nuclear developments may find certain offerings by the Department of Nuclear Engineering to be of interest, such as the medically oriented radiological sciences program, nuclear power plant engineering, applied plasma or radiation physics, nuclear materials engineering, and the interdepartmental program on structural mechanics in nuclear power technology.

Undergraduate Study

Bachelor of Science in Nuclear Engineering

The undergraduate programs in Nuclear Engineering prepare students for careers in the nuclear power industry or the applied radiation industry, including medical technology, or for graduate study in nuclear engineering and related disciplines. The field is very broad and the program is arranged to provide a variety of subject combinations appropriate for career preparation. Three specific options have been defined (fission, fusion, and radiological sciences), but other subject combinations may be selected to satisfy the needs of individual students.

The Department offers two undergraduate programs leading to a Bachelor of Science in Nuclear Engineering. The first, Course XXII, is normally completed in four years. The second, Course XXII-A, is part of a five-year Engineering Internship Program; it leads to both a Bachelor of Science and a Master of Science in Nuclear Engineering and combines study with industrial practice.

The background portion of the departmental program includes a science distribution preparation in differential equations (18.03) and in physics (8.03). In addition, an applied nuclear physics subject (22.02) is used to introduce many topics that are fundamentally important to nuclear engineering. Finally, a seminar is specified to provide familiarity with departmental academic and research activities (22.011 for fission, 22.012 for fusion, or 22.013 for radiological sciences).

Subjects in engineering principles are a major component of the departmental program. In this area, the student is expected to become familiar with the foundations of engineering practice. The required topics of study are strength of materials, fluid flow, thermodynamics, heat transfer, and computer modeling of physical systems. Many of the Institute departments offer subjects covering these topics, and there is considerable latitude in fulfilling this segment of the curriculum. Suitable subjects include 2.01 or 8.06 for strength of materials (Engineering Principles I); 2.20 or 8.263 for fluid mechanics (II); 2.40 or 6.018 for thermodynamics (III); 2.51 for heat transfer (IV); and 22.006 for computer modeling (V).

The final portion of the undergraduate program is a broadly based introduction to the specialties of nuclear engineering. The required topics of study include a laboratory subject, a subject dealing with physics as applied to nuclear reactors, and three subjects dealing with design and systems. Suitable subjects for the fission option include 22.09 for laboratory; 22.021 for applied physics; and 22.03, 22.031, 22.033 for design/systems. Suitable subjects for the fusion option include 22.069 for laboratory; 22.061 for applied physics; and 22.03, 22.031, 22.062 for design/systems. Suitable subjects for the radiological sciences option include 22.09 for laboratory; 22.021 for applied physics; and 22.04 plus two individually selected subjects for design/systems.

The choice of specific subjects and the order in which they are taken are arranged in consultation with the student's departmental advisor. The fission option is intended for students planning careers in design, analysis, and operation of fission reactors, and for graduate study in these areas. The fusion option is intended for students planning for graduate study and careers in areas of engineering research or development related to fusion reactors. The radiological sciences option is intended for students planning careers in medicine or biomedical engineering with particular emphasis on the applications of radiation in diagnostics and therapy. Information on each option is available from the student's departmental advisor or from the departmental undergraduate office (Room 24-204).

The degree programs in Course XXII and Course XXII-A are accredited by the Accreditation Board for Engineering and Technology.

Bachelor of Science in Nuclear Engineering Course XXII

Most requirements and options are described in the preceding paragraphs.

Engineering Design experience is an essential part of the curriculum, and the requirement of at least 36 units of engineering design and systems may be satisfied by an appropriate choice of subjects as approved by the advisor. The requirement may be partially satisfied by a design-oriented thesis or special topic (22.091).

A bachelor's degree thesis of 12 units is also required.

Bachelor of Science in Nuclear Engineering Course XXII

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements		**17 Subjects**
Science Requirement		5
Humanities, Arts, and Social Sciences Requirement		8
Science Distribution Requirement [2 subjects can be satisfied by 8.03 and 18.03 in the Departmental Program]		3
Laboratory Requirement [can be satisfied by 20.002, 22.069 or 22.09 in the Department Program]		1
	TOTAL Subjects	17
PLUS		
Departmental Program[1]		**Units**
Background:		**42**
8.03	Physics III, 12; 8.02**	
18.03	Differential Equations, 12; 18.02**	
22.02	Introduction to Applied Nuclear Physics, 12; 8.02, 18.02	
	Seminar, 6	
Engineering Principles:		**60**
	Engineering Principles I, 12	
	Engineering Principles II, 12	
	Engineering Principles III, 12	
	Engineering Principles IV, 12	
	Engineering Principles V, 12	
Nuclear Engineering Specialties:		**60**
	Laboratory, 12	
	Applied Physics, 12	
	Design and Systems, 36	
Thesis		**12**
Units in Departmental Program that also satisfy the General Institute Requirements		**(36)**
Unrestricted Electives		**48**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements		**186**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

1
Suitable subjects for seminar, engineering principles, laboratory, applied physics, and design/systems are given in the text.

Bachelor of Science in Nuclear Engineering
Course XXII-A

Nuclear Engineering Department students who participate in the Engineering Internship Program, described in detail in the School of Engineering section, are enrolled in Course XXII-A. The requirements for Course XXII-A are the same as for Course XXII, except that the 12 units of thesis are replaced by 12 units of 22.092 Engineering Internship. The program is structured as a five-year program leading to both a Bachelor of Science and a Master of Science in Nuclear Engineering. Students normally enter the program in their sophomore year at MIT. Each student must be selected by a participating company after application and an interview. The program consists of four work assignments at the same company. The first two are undergraduate work assignments designated as the required subject 22.092.

The award of the Master's degree is not automatic. To work for the S.M., the student must apply for graduate school and be formally accepted. In most cases the decision on such applications is made early in the student's fourth year.

Engineering design experience is an essential part of the Course XXII-A curriculum. The requirement of 36 units of engineering design and systems subjects may be satisfied in part by work assignments that are design-related. Otherwise, the requirement is to be satisfied by an appropriate selection of subjects, as approved by the student's advisor.

The Bachelor's thesis requirement is usually satisfied upon acceptance of the Master's thesis, which is prepared during the third and fourth work assignments (subject 22.92). If the student does not enter the Master's portion of the program for any reason, the student may substitute work done as part of the first two work assignments, provided that the student prepares a written proposal and a written report in thesis format that is acceptable to a faculty advisor. Otherwise, the student must follow the same steps for satisfying the thesis requirement as students in Course XXII.

Combined Bachelor's and Master's Programs

The five-year programs leading to a joint Bachelor of Science in chemical engineering, civil engineering, electrical engineering, mechanical engineering, nuclear engineering, or physics, and a Master of Science in nuclear engineering, are helpful to students who, early in their undergraduate studies, decide to pursue a graduate degree in nuclear engineering. Students desiring to enter such a program must meet the graduate admission requirements of the Department of Nuclear Engineering, and they must submit their applications for admission at the end of their junior year. If admitted, the student's program is arranged between the registration officers of the two participating departments. For further information, interested students should contact either their undergraduate department or the Department of Nuclear Engineering.

Inquiries

Further information on undergraduate programs, admissions, and financial aid may be obtained from Professor J. E. Meyer, Room 24-202, MIT, Cambridge, Massachusetts 02139, (617) 253-3830.

Bachelor of Science in Nuclear Engineering
Course XXII

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement		60
Humanities, Arts, and Social Sciences Requirement		72
Science Distribution Requirement can be satisfied by 8.03, 18.03, and 22.02 in the Departmental Program.		
Laboratory Requirement can be satisfied by a laboratory subject from the Department Program.		
Departmental Program[1]		**Units**
Background		**42**
8.03	Physics III, 12; 8.02*	
18.03	Differential Equations, 12; 18.02*	
22.02	Introduction to Applied Nuclear Physics, 12; 8.02, 18.02	
	Seminar, 6	
Engineering Principles		**60**
	Engineering Principles I, 12	
	Engineering Principles II, 12	
	Engineering Principles III, 12	
	Engineering Principles IV, 12	
	Engineering Principles V, 12	
Nuclear Engineering Specialties:		**60**
	Laboratory, 12	
	Applied Physics, 12	
	Design and Systems, 36	
Thesis		**12**
Unrestricted Electives:		**60**
Total Units Required for the S.B. Degree		**366**

*Alternate prerequisites are listed in the subject description.

[1] Suitable subjects for seminar, engineering principles, laboratory, applied physics, and design/systems are given in the text.

Graduate Study

The Nuclear Engineering profession is exceptionally broad and many undergraduate disciplines provide suitable preparations for graduate study.

An undergraduate degree in physics; engineering physics; chemistry; mathematics; metallurgy; or chemical, civil, electrical, mechanical, or nuclear engineering furnishes suitable preparation for graduate study in nuclear engineering. Optimum undergraduate preparation would include the following:

Physics. At least two years, equivalent to MIT subjects 8.01, 8.02, 8.03, and 8.04 or 8.211, and for graduate study in applied plasma physics or applied radiation physics, the equivalent to MIT subjects 8.06 and 8.07, as well.

Mathematics. At least two and one-half years, equivalent to MIT subjects 18.01, 18.02, 18.03, 18.075, and 18.076.

Chemistry. At least one term of general, inorganic, and physical chemistry.

Engineering Fundamentals. At least one term equivalent to MIT subjects 2.01 or 10.302, 10.301 or 10.13. Students may obtain equivalent background by taking 22.311 Energy Engineering Principles.

Prospective graduate students should make every effort to complete undergraduate preparation before starting graduate study. Students whose preparation is incomplete may make up their deficiencies after admission to graduate study, but they need more time to complete the graduate program.

Students who expect to apply for admission to a graduate course in Nuclear Engineering should discuss their undergraduate programs with the Department's Registration Officer, preferably before the end of their junior year. Applicants for admission are not required to take the Graduate Record Examination.

Master of Science in Nuclear Engineering Course XXII

The object of the master's program is to give the student a good general knowledge of nuclear engineering and to provide a foundation either for productive work in the nuclear field or for more advanced graduate study. The general requirements for this degree are listed in the Graduate Education chapter. Subject 22.111 Nuclear Physics for Engineers I, or its equivalent is required for all master's degree candidates.

Other subjects may be selected in accordance with the student's particular field of interest. Most master's candidates specialize in one of five alternative fields: fission reactor technology, applied plasma physics, radiation science and technology, nuclear materials engineering, and radiation health physics. Detailed descriptions of the subjects available in each of these areas may be found under the Department's descriptions of subjects in Chapter VIII.

Students specializing in radiation health physics follow a special two-year curriculum that includes the core subjects General Health Physics, Nuclear Radiation Measurement and Protection, Introductory Applied Nuclear Physics, and Radiobiology. Some subjects may be taken at the Harvard School of Public Health.

Students with adequate undergraduate preparation normally need one full year to complete the requirements for the Master of Science. Additional information concerning the requirements for the Master of Science in Nuclear Engineering, including lists of recommended subjects, may be obtained from the Department of Nuclear Engineering.

Master of Science in Technology and Policy

Students interested in applying their nuclear engineering background to problems of policy and socioeconomic assessment of technology may apply for the interdepartmental Master of Science Program in Technology and Policy. This program combines subjects in advanced technology in the particular field of the student's choosing with subjects in economics, systems analysis, political science, and law. General requirements and application procedures are described in Chapter VI.

Master of Science in the Management of Technology

Students who would like to apply their nuclear engineering background and at least five years of technical work experience to issues in technical management may want to explore the Joint Program in the Management of Technology. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, this program entails a rigorous twelve-month curriculum, focusing on management principles for technical people in a technical environment. The Program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program and application procedures are described in Chapter VI.

Nuclear Engineer

The program of study leading to the Nuclear Engineer's degree provides deeper knowledge of nuclear engineering than is possible in the master's program and is intended to train students for creative professional careers in engineering application or design.

General requirements for this degree, described in Chapter IV, include 162 units of subject credit plus a thesis. Each student must plan an individually selected program of study, to be approved in advance by the faculty advisor, and must complete, and orally defend, a substantial project of significant engineering value.

The principal areas of study are nuclear reactor physics, nuclear reactor engineering, nuclear materials engineering, nuclear fuel management, radiation science and technology, and applied plasma physics. The objectives of the program are to provide the candidate with a broad knowledge of the profession and to develop competence in engineering applications or design. The emphasis in the program is more applied and less research-oriented than the doctoral program.

The engineering project required of all candidates for the Nuclear Engineer's degree is generally the subject of an Engineer's thesis. A student with full undergraduate preparation normally needs two years to complete the program. A student who satisfies the requirements for the Engineer's degree is simultaneously approved for the S.M. by the Department of Nuclear Engineering. Additional information may be obtained from the Department.

Doctor of Philosophy and Doctor of Science

The program of study leading to either the Doctor of Philosophy or the Doctor of Science degree aims to give a comprehensive knowledge of nuclear engineering or radiation science and technology, to develop competence in advanced engineering research, and to develop perspective in assessing the role of nuclear science and technology in our society.

General requirements for the doctorate are given in the Graduate Education chapter of this catalogue and in the *Graduate School Manual*. The specific requirements of the Department of Nuclear Engineering are the General Examination, the Major/Minor Program, and the doctoral thesis.

Upon satisfactory completion of the requirements, the student ordinarily receives a Ph.D. unless he or she requests an Sc.D. The requirements for both degrees are the same.

Prior to starting doctoral research, each student is required to pass a general examination demonstrating adequate undergraduate preparation in physics, chemistry, mathematics, and engineering fundamentals, and comprehensive knowledge at the graduate level of a chosen field in nuclear engineering.

Doctoral candidates may elect to study and be examined in one of the following fields: fission reactor physics, fission reactor engineering, applied plasma physics, applied radiation physics, nuclear materials engineering, fusion reactor technology, nuclear and alternative energy systems and policy, and radiological science. Details of the doctoral examination in each of these fields may be obtained from the Department.

The field of radiological sciences focuses on diverse applications of radiation in medicine. In addition to a central concern with ionizing radiation, radiological sciences encompass such technologies as ultrasound, laser light, and nuclear magnetic resonance. The curriculum is a four- to five-year commitment leading to the Ph.D. or Sc.D. degree that can be pursued in medical therapy, imaging and diagnostic technology, radiation biophysics, or radio pharmaceutical chemistry. While most core subjects are taken at MIT, research is conducted primarily at Harvard-affiliated hospitals, the Harvard School of Public Health, and MIT, depending upon the student's specialty area.

Candidates for a doctoral degree must also satisfactorily complete (with an average grade of B or better) an approved program of advanced studies. The program requires that students take not less than 60 credit hours of subjects (excluding special problems), of which at least 36 must comprise a field of specialization (the "Major") that will be closely related to the student's doctoral thesis topic. Twenty-four units (the "Minor") must consist of coordinated subjects clearly outside the field of specialization.

Doctoral research may be undertaken either in the Department of Nuclear Engineering or in a nuclear-related field in another department. Appropriate areas of research are described generally in the introduction to the Department, and a detailed list may be obtained from the Department of Nuclear Engineering.

Research Facilities

The departmental programs are supported by a number of outstanding experimental facilities for advanced research in nuclear engineering.

The MIT Research Reactor in the Nuclear Reactor Laboratory operates at a power of 5,000 kw and is fueled with U-235 in a compact light-water cooled core surrounded by a heavy-water reflector. It is one of the finest university research reactors in the world. Details of the Laboratory's research programs and facilities are given in Chapter VI.

The Department utilizes extensive experimental plasma facilities for production and confinement of large volumes of highly ionized plasmas and for studies of plasma turbulence, particle motions, and other phenomena. High-power lasers and other equipment are available both for plasma diagnostics and for study of basic physical interactions. The Department has facilities to support a unique program of controlled fusion engineering studies and has its own well-equipped graduate laboratory for instruction on plasma laboratory techniques.

The Department has played a major role in the design and operation of the high field Tokamak fusion device ALCATOR and in the design of the fusion magnetic mirror device TARA, both projects of the Plasma Fusion Center. ALCATOR is capable of producing dense, hot plasmas near the regime of fusion interest, and serves as an important educational and research facility.

Most of the departmental research on plasmas and controlled fusion is done in the Plasma Fusion Center, described in detail in Chapter VI.

The Whitaker Laboratory of Computer-Aided Microscopy and Image Technology operates sophisticated scanning and transmission electron microscopes and light microscopes for microscopic analysis of materials. The facility has full capability in sample preparation and utilizes a dedicated computer for data analysis with an emphasis on quantitative work.

In addition to the above facilities, the Department has a nuclear instrumentation laboratory, a plasma physics laboratory, a 14 MeV neutron source, and two subcritical natural-uranium reactors, one moderated by water and the other by graphite. Laboratory space and shop facilities are available for research in all areas of nuclear engineering. MIT's extensive computer facilities are used in research and graduate instruction. The Whitaker Laboratory of Microscopy is available for ultrastructural research in materials.

Financial Aid

Financial aid for graduate students is available in the form of research and teaching assistantships, Department-administered fellowships, and supplemental subsidies from the College Work-Study Program. Assistantships are awarded to students with very good academic records. The duty of a teaching assistant is to assist a faculty member in the preparation of course materials and the conduct of classes, and that of a research assistant is to work on a research project under the supervision of one or more faculty members.

Fellowships are mostly awarded in April for the following academic year. Assistantships are awarded on a semester basis. The assignment of teaching assistants is made before the start of each semester while research assistants can be assigned at any time. Fellowships and research assistantships usually go to students already enrolled in the Department; for entering students the majority of the aid therefore will be in the form of teaching assistantships.

Application for financial aid should be made to Professor M. Kazimi, Room 24-105, MIT, Cambridge, Massachusetts 02139, (617) 253-4206.

Inquiries

Additional information on graduate admissions and academic and research programs may be obtained from the Department's Graduate Office, Room 24-105, MIT, Cambridge, Massachusetts 02139, (617) 253-3814.

Department of Ocean Engineering

T. Francis Ogilvie, Ph.D.
Professor of Ocean Engineering
Head of the Department

Professors

Arthur Bernard Baggeroer, Sc.D.
Professor of Ocean and Electrical Engineering

Alexander Douglas Carmichael, Ph.D.
Professor of Power Engineering

Chryssostomos Chryssostomidis, Ph.D.
Professor of Naval Architecture
Director, MIT Sea Grant College Program

Ira Dyer, Ph.D.
Professor of Ocean Engineering

Ernst Gabriel Frankel, Ph.D., D.B.A.
Professor of Marine Systems

Justin Elliot Kerwin, Ph.D.
Professor of Naval Architecture

Patrick Leehey, Ph.D.
Professor of Ocean and Mechanical Engineering

Koichi Masubuchi, D.Eng.
Professor of Ocean Engineering and Materials Science
(On leave, spring)

Jerome H. Milgram, Ph.D.
Professor of Naval Architecture
(On leave, fall)

John Nicholas Newman, Sc.D.
Professor of Naval Architecture
(On leave)

J. D. Nyhart, J.D.
Professor of Ocean Engineering and Management

Barrick Frank Tibbitts, Nav.E.
Professor of Naval Architecture

John Kim Vandiver, Ph.D.
Professor of Ocean Engineering
Director, Experimental Study Group

Tomasz Wierzbicki, Sc.D.
Professor of Applied Mechanics
(On leave)

Associate Professors

Dale George Karr, Ph.D.
Associate Professor of Ocean Engineering

Judith Tegger Kildow, Ph.D.
Associate Professor of Ocean Policy

Henry Stuart Marcus, D.B.A.
Associate Professor of Marine Systems

Harilaos Nicholas Psaraftis, Ph.D.
Associate Professor of Marine Systems

Paul Demetre Sclavounos, Ph.D.
Associate Professor of Naval Architecture

Henrik Schmidt, Ph.D.
Associate Professor of Ocean Engineering

Paul E. Sullivan, Ocean E.
Associate Professor of Naval Architecture

Michael Stefanos Triantafyllou, Sc.D.
Associate Professor of Ocean Engineering

Dick Kau-Ping Yue, Sc.D.
Associate Professor of Ocean Engineering

Assistant Professors

Amiram Moshaiov, Ph.D.
Assistant Professor of Ocean Engineering

Nicholas Marinos Patrikalakis, Ph.D.
Assistant Professor of Ocean Engineering
Henry L. Doherty Professor in Ocean Utilization

Senior Lecturers

David Valentine Burke, Ph.D.
Harry A. Jackson, B.S.

Lecturers

John E. Agapakis, Ph.D.
John G. Arrison, M.A.
Howard M. Bunch, M.B.A.
Leonard Grantner, D.Eng.Sc.
Maurice M. Sevik, Ph.D.
Paul Whitney Sparks, B.S.
Peter T. Tarpgaard, Ph.D.
Benjamin Whang, Ph.D.

Administrative Officer

Patricia A. LeBlanc-Gedney, B.S.

Postdoctoral Associates

Fernando de Carvalho Frimm, Ph.D.
George S. Triantafyllou, Ph.D.

Research Engineers

Michael S. Drooker, Ocean E.
Marvin H. Duncan, S.M.
Sumner Dean Lewis, B.S.
Spyridon A. Kinnas, Ph.D.

Research Affiliate

Gregory Lynn Duckworth, Ph.D.

Professors Emeriti

Martin Aaron Abkowitz, Ph.D.
Professor of Ocean Engineering, Emeritus

John Harvey Evans, B.Eng.
Professor of Naval Architecture, Emeritus

Alfred Adolf Heinrich Keil, Dr.Rer.Nat.
Professor of Ocean Engineering, Emeritus
Ford Professor of Engineering, Emeritus

Philip Mandel, B.S.
Professor of Naval Architecture, Emeritus

Department of Ocean Engineering

(Course 13)

Undergraduate Study

For centuries the oceans have served societal needs by providing avenues of transportation, resources of food and minerals, and natural barriers of defense. These uses of the ocean are perhaps even more important today as the world faces problems of growing populations and shrinking resources. Out of the need for increased utilization of the ocean has come a heightened sense of purpose. Simply stated, the task in ocean engineering is to use the oceans effectively and wisely.

The Department of Ocean Engineering provides the essential skills that ultimately enable its students to conceive, initiate, and direct complex engineering projects. Such tasks demand flexible and adaptive engineering minds. The degree requirements in Ocean Engineering begin with the same basic mathematics, science, and engineering subjects as other traditional engineering disciplines and then extend beyond to prepare a professional who is capable of responding to the broad demands of complex engineering tasks. Through selection of degree programs and elective subjects, students may concentrate in areas such as structures, fluid mechanics, or naval architecture.

For nearly a century, MIT has been a leading center of ship research and design, and is widely recognized for its contributions in such areas as hydrodynamics, ship structural mechanics and dynamics, propeller design, and overall ship design. The Pratt School of Naval Architecture and Marine Engineering, which was established through a bequest to MIT in 1912, is an integral part of the Department of Ocean Engineering. Building upon this historical base, the Department's curriculum today offers studies in all systems that must operate in an ocean environment.

Marine transportation encompasses broad questions of international trade. The ocean engineer must be able to assess in an integrated fashion a wide range of technical, economic, and political considerations. Other aspects of marine transportation include designing deep-water ports, integrating harbor facilities with land-based transportation systems, and planning new uses of waterways to help solve urban transportation problems.

Oil and gas beneath the ocean floor are increasingly important sources of energy. An ocean engineer is concerned with all phases of discovering, producing, and delivering offshore petroleum resources, a complex and demanding task. Also of central importance is the development of new methods to protect marine wildlife and coastal regions against the undesirable side effects of offshore oil production. Mining of seafloor minerals is assuming greater importance, and the ocean engineer has the task of developing technology for locating and recovering valuable minerals that lie beneath the oceans. Much new technology is required to explore the feasibility of ocean mining; more still is needed to make it economically attractive and compatible with the environment.

Once regarded as an inexhaustible source of food, the oceans are now approaching critical levels of depletion for some species. Engineering techniques of analysis and prediction are essential to maintain the delicate natural balances of the oceans. The ocean engineer, together with marine biologists, aquatic ecologists, and public policy planners, has a critical role to play in managing ocean resources to ensure survival of marine species and continuing supplies of food for the world.

Oceans serve as natural barriers of defense for many nations, and careers in ocean-related defense offer some students a logical extension of their ocean engineering education. The Department offers subjects designed to enable people to cope with technologies relevant to modern naval systems, including ship design alternatives, seafloor habitats, sonar systems, and underwater navigation and communication.

The education of an ocean engineer or a naval architect revolves around three central components. The first is a firm foundation in such basics as hydrodynamics, structural mechanics, vibratory phenomena, energy conversion, materials, and electronics. Second, the engineer needs broad exposure and practical experience in skills such as analysis and design. Third, the context for specific applications needs to be understood. The Department's undergraduate and graduate programs combine these components in a balanced way to provide an educational base upon which to build a rewarding career.

Once a student has attained the engineering basics, individualized programs to meet particular interests are strongly encouraged. The Department's faculty has wide and continuing research and industrial experience. Departmental facilities — including a variable-pressure propeller tunnel, a ship model towing tank, a channel for oil-water interface studies, an acoustics and vibration laboratory, a design laboratory, and computer facilities — offer a variety of opportunities for laboratory experience.

Bachelor of Science in Ocean Engineering, in Naval Architecture and Marine Engineering, or without designation Course XIII

The basic program offered by the Department is designed for students interested in engineering aspects of ocean sciences, ocean exploration, and the utilization of the oceans for transportation, defense, and/or resources. The program leads to the Bachelor of Science in Ocean Engineering, in Naval Architecture and Marine Engineering, or without designation of field. The curriculum without designation of field permits pursuit of broader marine-related interests. Graduates are prepared for work in industry or government, or for further study in graduate school.

All Course XIII undergraduates take the same required subjects in mathematics, science, and engineering fundamentals, along with subjects fulfilling the General Institute Requirements. Some departmentally prescribed subjects may be replaced by other subjects if such substitutions enhance student objectives. The elective program consists of two parts: planned electives, which are designed to meet the student's Course objective, and unrestricted electives, which permit further study in specialized areas or a broadening of the student's overall educational experience.

The Department offers counseling to students wishing to use some combination of planned and unrestricted electives for environmental studies. Such a course of study is similar to the other four-year MIT programs, supplemented with elective studies, that prepare students for environmentally related work.

Versions of the Course XIII program leading to the Bachelor of Science in Ocean Engineering, or to the Bachelor of Science in Naval Architecture and Marine Engineering, are accredited by the Accreditation Board for Engineering and Technology, while those leading to the Bachelor of Science without designation of field are not.

Bachelor of Science in Ocean Engineering, in Naval Architecture and Marine Engineering, or without designation Course XIII

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement[1]	8
Science Distribution Requirement [2 subjects can be satisfied from among 2.01, 2.40, and 18.03 in the Departmental Program]	3
Laboratory Requirement [half the requirement can be satisfied by 13.901 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:[2,3,4]	138
One of the following three subjects:	
2.02 Introduction to Systems Dynamics, 12; 8.01, 18.02	
6.003 Signals and Systems, 15; 6.001, 6.002	
13.80J Mechanical Vibration, 12; 2.03J or 13.003J	
plus	
One of the following two subjects:	
2.20 Fluid Mechanics, 12; 18.02, *18.03*	
1.60 Fluid Dynamics, 12; 18.03	
plus	
13.00 Computer-Aided Hydrostatics and Hull Surface Definition, 12; 8.01, 18.02	
13.003J Dynamics, 12; *2.01*, 2.02, 18.03	
13.021 Marine Hydrodynamics I, 12; 2.20**	
13.10J Introduction to Structural Mechanics, 12; 2.01**	
13.40 Introduction to Computer-Aided Ocean Engineering Design, 12; 2.01, 13.00; 2.20**	
13.700-13.709 Special Problems in Ocean Engineering, 12	
13.901 Ocean Engineering Laboratory I, 6; 2.20	
18.03 Differential Equations, 12; 18.02**	
2.01 Mechanics of Solids, 12; 8.01, 18.02	
2.40 Thermodynamics, 12; 8.02, *18.03*	
Restricted Electives:[5,6]	30
Thirty units are to be chosen by the student and faculty advisor to attain preparation for a career in Ocean Engineering or in Naval Architecture and Marine Engineering, or to attain another educational objective defined by the student.	
Units in Departmental Program that also satisfy the General Institute Requirements	(30)
Unrestricted Electives	48
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	186

Bachelor of Science in Ocean Engineering, in Naval Architecture and Marine Engineering, or without designation Course XIII-C

Course XIII-C is an Engineering Internship program that enables students to combine professional experience with their academic work, while at the same time providing for part of their educational expenses. The four-year program leads to the Bachelor of Science in Naval Architecture and Marine Engineering, or in Ocean Engineering, or without designation. Students in the internship program also may apply for admission to the Graduate School to obtain the Bachelor of Science concurrently with the Master of Science at the end of their fifth year. This program is part of the Engineering Internship Program, described in detail in the School of Engineering section.

All MIT sophomores in good standing can apply for entrance to the program. Alternating periods at the Institute and at cooperating work sites are arranged so that graduation is not delayed beyond the normal date.

The companies and laboratories participating in the internship program cover all important aspects of ocean engineering, including naval architecture and marine engineering. Assignments with these organizations provide opportunities to participate in activities such as construction, testing, design, development, research, and technical planning.

Versions of the Course XIII-C program leading to the Bachelor of Science in Ocean Engineering, or in Naval Architecture and Marine Engineering, are accredited by the Accreditation Board for Engineering and Technology, while those leading to the Bachelor of Science without designation of field are not.

The Course XIII-C curriculum is identical to Course XIII, except that 13.771 Engineering Internship (12 units) and 13.772 Industrial Practice in Ocean Engineering (12 to 36 units) are taken in place of Special Problems in Ocean Engineering. Further details may be obtained from the Department. The Department also suggests that 13.901 and 13.902 be taken to satisfy the Institute Laboratory Requirement.

Combined Bachelor's and Master's Degree Program

Programs leading to a joint Bachelor of Science (in aeronautics and astronautics, civil engineering, electrical engineering, mechanical engineering, naval architecture and marine engineering, or ocean engineering), and a Master of Science (in ocean engineering or in naval architecture and marine engineering), are available to students who, early in their undergraduate studies, decide to pursue a graduate degree in ocean engineering or naval architecture and marine engineering. Students desiring to enter such a program must meet the graduate admission requirements of the Department of Ocean Engineering. They must submit their applications for admission at the end of their junior year. If admitted, the student's program is arranged in consultation with the registration officers of the two participating departments. For further information, interested students should contact the Departmental Student Administration Office.

Inquiries

Further information on undergraduate programs, admissions, and financial aid may be obtained by contacting Professor Dick K-Y Yue, Room 5-326A, MIT, Cambridge, Massachusetts 02139, (617) 253-4366.

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

**Alternate prerequisites are listed in the subject description.

1
14.01 Economic Principles I is required in the Humanities, Arts, and Social Sciences program if another subject in the field of economics is not included in the elective program.

2
The Department allows substitution of subjects of similar content after consultation with the faculty advisor.

3
For the degree without designation of field delete 13.40 Introduction to Computer-Aided Ocean Engineering Design from the list of required subjects and increase the Unrestricted Elective units by 12.

4
Students must receive a grade of C or better in core subjects which serve as prerequisites for other Departmental core subjects before continuing in the Departmental program.

5
For the degree in Ocean Engineering, students are required to take at least thirty units from the following areas: Dynamics, Design, Hydrodynamics, Instrumentation and Electronics, Management and Economics, Materials and Fabrication, Ocean Acoustics, Ocean Environment, Power and Propulsion, Probabilistic Systems Analysis, and Structures. Selected subjects need not be in different areas.

6
For the degree in Naval Architecture and Marine Engineering, at least one subject from the area of Power and Propulsion must be included in the 30 units of elective subjects described in footnote 4 above.

Graduate Study

Bachelor of Science in Ocean Engineering, in Naval Architecture and Marine Engineering, or without designation Course XIII

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement		60
Humanities, Arts, and Social Sciences Requirement[1]		72
The Science Distribution Requirement can be satisfied by 2.01, 2.40, and 18.03 in the Departmental Program.		
The Laboratory Requirement can be satisfied by 13.901 in the Departmental Program, plus an appropriate subject totaling		6
Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects[2,3,4]		138
One of the following three subjects:		
2.02	Introduction to Systems Dynamics, 12; 8.01, 18.02	
6.003	Signals and Systems, 15; 6.001, 6.002	
13.80J	Mechanical Vibration, 12; 2.03J or 13.003J	
	plus	
One of the following two subjects:		
2.20	Fluid Mechanics, 12; 18.02, *18.03*	
1.60	Fluid Dynamics, 12; 18.03	
	plus	
13.00	Computer-Aided Hydrostatics and Hull Surface Definition, 12; 8.01, 18.02	
13.003J	Dynamics, 12; *2.01*, 2.02, 18.03	
13.021	Marine Hydrodynamics I, 12; 2.20*	
13.10J	Introduction to Structural Mechanics, 12; 2.01*	
13.40	Introduction to Computer-Aided Ocean Engineering Design, 12; 2.01, 13.00; 2.20*	
13.700-13.709	Special Problems in Ocean Engineering, 12	
13.901	Ocean Engineering Laboratory I, 6; 2.20	
18.03	Differential Equations, 12; 18.02*	
2.01	Mechanics of Solids, 12; 8.01, 18.02	
2.40	Thermodynamics, 12; 8.02, *18.03*	
Restricted Electives:[5,6]		30
Thirty units are to be chosen by the student and faculty advisor to attain preparation for a career in Ocean Engineering or in Naval Architecture and Marine Engineering, or to attain another educational objective defined by the student.		
Unrestricted Electives[3]		54
Total Units Required for the S.B. Degree		360

*Alternate prerequisites are listed in the subject description.

1
14.01 Economic Principles I is required in the Humanities, Arts, and Social Sciences program if another subject in the field of economics is not included in the elective program.

Graduate study in the Department of Ocean Engineering can lead to the following degrees: Master of Science; Ocean Engineer; Naval Engineer; Doctor of Philosophy; or Doctor of Science.

An acceptable program of subjects plus an acceptable thesis leading to the Master of Science usually requires from one to two academic years, depending upon undergraduate preparation.

The Ocean Engineer and Naval Engineer degrees require at least two years, including a substantial thesis.

The Doctor of Science or Doctor of Philosophy with a specification in an ocean-related field usually requires more than three years following a Bachelor of Science.

Students, together with their program advisors, usually can tailor their programs of graduate study to suit individual interests and career objectives. Detailed Departmental requirements are available from the Departmental Student Administration Office.

Entrance Requirements for Graduate Study

Undergraduate preparation for admittance to graduate study in the Department of Ocean Engineering ideally should be equal in quality, quantity, and breadth of coverage to the Department's undergraduate curricula. An undergraduate degree in ocean engineering is not required.

2
The Department allows substitution of subjects of similar content after consultation with the faculty advisor.

3
For the degree without designation of field delete 13.40 Introduction to Computer-Aided Ocean Engineering Design from the list of required subjects and increase the Unrestricted Elective units by 12.

4
Students must receive a grade of C or better in core subjects which serve as prerequisites for other Departmental core subjects before continuing in the Departmental program.

5
For the degree in Ocean Engineering, students are required to take at least thirty units from the following areas: Dynamics, Design, Hydrodynamics, Instrumentation and Electronics, Management and Economics, Materials and Fabrication, Ocean Acoustics, Ocean Environment, Power and Propulsion, Probabilistic Systems Analysis, and Structures. Selected subjects need not be in different areas.

6
For the degree in Naval Architecture and Marine Engineering, at least one subject from the area of Power and Propulsion must be included in the 30 units of elective subjects described in footnote 4 above.

If undergraduate preparation is lacking in one or more areas, the deficiencies may be made up concurrently with graduate work, usually by successfully completing one or a few upper level undergraduate subjects. Undergraduate subjects so required may not count toward advanced degree requirements. Somewhat less broad undergraduate work is required of candidates for the degree of Master of Science without specification, provided that the student has a correspondingly increased competence in areas pertinent to his or her proposed graduate program.

Ocean Engineering/ Naval Architecture and Marine Engineering Course XIII

The Department's curriculum leading to a Master's degree in Ocean Engineering is based on a broad working knowledge of all the basic engineering skills. The intended outcome of this program is a person whose main interest is the development of the ocean for the good of humanity, and in following this ambition is prepared to use whatever engineering disciplines are needed to address the problem at hand. As a part of the more general field of Ocean Engineering, Naval Architecture and Marine Engineering is concerned with all aspects of waterborne vehicles operating on, below, and just above the sea surface. The S.M. degree in Naval Architecture and Marine Engineering is intended to develop an individual who plans to concentrate in areas related to waterborne vehicles and/or their subsystems.

Major fields of study or specialization include (but are not limited to) the following:

Applied mechanics
Environmental engineering
Fluid mechanics
Hydrodynamics
Marine acoustics
Marine data systems engineering
Marine engineering
Marine materials and fabrication
Marine systems
Offshore engineering
Offshore platform design
Seafloor engineering
Ship design
Ship and offshore rig dynamics
Ship propulsion
Ship systems
Structural mechanics

Doctoral degrees are offered in the fields of Ocean Engineering and Naval Architecture and Marine Engineering. Students are admitted to the doctoral program after successful completion of the appropriate qualifying examinations. The student's program must be acceptable to the Departmental Committee on Graduate Students, both with respect to depth in the major area and broadness in collateral areas. Details on the examination process and other requirements, including the doctoral thesis, may be obtained from the Departmental Student Administration Office.

There are also a number of interdepartmental doctoral programs available to students in the Department. Details may be found in Chapter VI.

Naval Construction and Engineering
Course XIII-A

This Program provides appropriate academic background for naval officers who later actively participate in concept formulation, design, and construction of naval vessels. In addition to general engineering and science and a core program of subjects in ocean engineering, each student follows one of several specialized curricula in aspects of, or applicable to, naval construction and engineering.

The Program leads to the Naval Engineer or Master of Science. For programs leading to the Naval Engineer, a Master of Science may be awarded simultaneously upon recommendation of the Department or of some other department related to the student's specialty. For programs leading to the Master of Science, an additional Master of Science may be awarded simultaneously in a second field of specialization upon recommendation of the department represented by that field.

Ocean Systems Management
Course XIII-B

The XIII-B Program in Ocean Systems Management offers both Master of Science and Doctor of Philosophy degrees.

The Master's program is intended for students with solid engineering backgrounds who are interested in the business and government management aspects of ocean engineering systems and activities, including ocean transportation, marine resource development, public policy and ocean use, ocean mining, ports, and fisheries. Technical background should consist of a S.B. degree in engineering or science. Background should include at least one undergraduate subject each in differential equations, probability, and microeconomics. Any deficiency should be eliminated during the first term at MIT. Students not possessing a background in ocean engineering are required to take 13.40 Introduction to Computer-Aided Ocean Engineering Design.

Depending on background preparation, a student entering this program can take from one to two years to complete the degree. The program can be accomplished in one year by a Department undergraduate who carefully schedules his or her elective time from the junior year on. Such a student is awarded concurrently an S.M. in Ocean Systems Management and an S.B. degree. Further information on the Master's program requirements can be obtained from the Departmental Student Administration Office.

The doctoral degree program in Ocean Systems Management requires the development of new knowledge that enhances the state of the art in this area. To achieve that goal, the student is expected to complete a program of study and write a dissertation that successfully integrates theory, methodology, and experience in the fundamental disciplines that constitute the Ocean Systems Management area, such as engineering, economics, business administration, operations research, public policy analysis, and law. Students are admitted to the doctoral program after passing the appropriate written and oral qualifying examinations. Further information on the doctoral program requirements and examination process may be obtained from the Departmental Student Administration Office.

Ocean Engineer or Naval Engineer

The programs leading to the Ocean Engineer or Naval Engineer degrees require a higher level and significantly broader range of professional competence in engineering than that required for the S.M. degree. The program for an Engineer's degree ordinarily includes subjects in the areas of economics, industrial management, and public policy or law, and at least 12 units of comprehensive design. Should the student be working toward the simultaneous award of the Engineer and Master's degrees, a single thesis is generally acceptable, provided it is appropriate to the specifications of both degrees and demonstrates the educational maturity expected of candidates for the higher degree. Additional information on Departmental requirements is available from the Departmental Student Administration Office.

Technology and Policy (S.M.)

The Department also offers a Master's degree in Technology and Policy. This program educates students with a strong technical foundation in a marine-related field as well as a strong competence in dealing with policy issues. This program is interdepartmental and is described in Chapter VI. Requirements for entry into this program are the same as those required for the XIII-B Program with adjustments made for the special requirements of the Technology and Policy Program.

Transportation (S.M.)

The interdepartmental degree of Master of Science in Transportation is offered in cooperation with the Center for Transportation Studies. Most ocean engineering students studying transportation at the Master's level are enrolled in this interdepartmental program. Requirements for the Master of Science in Transportation are described in Chapter VI.

Management of Technology Program

Individuals interested in applying their ocean engineering background and at least five years of technical work experience to issues in technical management may apply for admission to the Management of Technology Program. Jointly developed and offered by MIT's School of Engineering and the Sloan School of Management, the program entails a rigorous twelve-month curriculum, focusing on management principles for technical persons in a technical environment. The program is designed for scientists and engineers on a career path requiring increasing managerial responsibilities for technical activities. Details of the program are described in Chapter VI.

Joint MIT-Woods Hole Oceanographic Institution Program
Course XIII-W

A joint program with WHOI is intended for students whose primary career objective is oceanographic engineering. Students divide their academic and research efforts between the campuses of the two institutions. While in residence at MIT, students enrolled in this course follow a program similar to that of other students in the Department. The program is described in more detail under the section at the end of this chapter on MIT's Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution.

Assistantships and Graduate Scholarships

There are a limited number of teaching and research assistantships available to graduate students in the Department each year. These are awarded on the basis of both qualification and need. The duties associated with these assistantships contribute directly to the assistant's educational program. An assistant may not register for more than 36 units per term, depending on the appointment held. Additional registration may be allowed when directly connected with an assistant's assigned duties.

A limited number of awards and scholarships are available to graduate students in the Department. Scholarships are awarded each year by the Society of Naval Architects and Marine Engineers. These awards can be used for study at any institution of the recipient's choice and usually are awarded to applicants who, through their education or their professional work, have evidenced strong interest in some field of naval architecture and marine engineering or in ocean engineering. Fellowships are also awarded each year by the Office of Naval Research (ONR) and the National Science Foundation (NSF).

Prospective students are invited to communicate with the Department regarding any of these educational and financial opportunities. Applications for the Society of Naval Architects and Marine Engineers Graduate Fellowships, Office of Naval Research, and National Science Foundation fellowships are made directly to the appropriate society. Inquiries for the fall term should be made late in the preceding fall term.

Inquiries

Additional information concerning academic programs, research opportunities, admissions, and financial aid may be obtained by writing to the Student Administrator, Department of Ocean Engineering, Room 5-225, MIT, Cambridge, Massachusetts 02139, (617) 253-1994.

School of Humanities and Social Science

Economics (Course 14)
Humanities (Course 21)
Linguistics and Philosophy (Course 24)
Political Science (Course 17)
Program in Science, Technology, and Society (STS)



The School of Humanities and Social Science reflects the great diversity of MIT today. In a university whose activities center around science and technology, the School represents the main fields of the liberal arts. Strong graduate programs exist in economics, linguistics, philosophy, and political science; students and faculty participate extensively in the research activities of numerous centers, laboratories, and departments outside the School. There is an ambitious and steadily broadening program of undergraduate education, which includes majors in economics, philosophy, language and mind, political science, and the various areas in the humanities, plus an interdisciplinary major in science or engineering and the humanities. A flourishing program of extracurricular activities attracts many students, notably in drama and in music. Student participation in musical activities is, indeed, perhaps more extensive at MIT than at any other major university, with a vigorous symphony orchestra, several strong choral groups, a fine jazz band, a concert band, and a wide variety of similar groups.

The graduate programs, while admitting relatively small numbers of students, are among the strongest at MIT. The *esprit de corps* is strong and there is a marked emphasis on developing new and exciting fields of inquiry. Many students take advantage of the opportunity to develop close associations with such interdisciplinary centers as the Center for International Studies, the Artificial Intelligence Laboratory, the Energy Laboratory, the Research Laboratory of Electronics, the Program in Psychology, the Center for Cognitive Science, and the Statistics Center. A new doctoral program in the History and Social Study of Science and Technology has been introduced by the History Faculty and the Programs in Anthropology/Archaeology and Science, Technology, and Society. Some of the graduate programs stress the use of mathematical and computer-oriented skills, but many doctoral theses are concerned with nonquantitative social science or humanistic topics. Moreover, graduate students are not entirely confined to the established doctoral programs. There is always room for a highly motivated student to develop his or her own program.

The research achievements of the School are perhaps best known to the world at large through the widely publicized achievements of certain distinguished members of the faculty. The chief emphasis of research in the School, however, as in the rest of the Institute, has been less on the activities of brilliant individuals than on teamwork. The Department of Economics and the Sloan School of Management cooperate closely in a number of

branches of applied economics. Studies of the labor market are conducted by economists, sociologists, and political scientists. A long-established concern with science and public policy involves people all over the Institute, and is particularly strong in the Department of Political Science and the Program in Science, Technology, and Society. A growing interest among musicians in acoustics and computers leads them to work jointly with electrical engineers. As the engineering departments have become increasingly concerned with questions of applied social science, such as energy management, urban transportation problems, and the exploitation of the sea bed, new opportunities have emerged for collaboration.

Undergraduates benefit in a variety of ways from these advanced research and training programs. Students majoring in economics, philosophy, and political science, for example, take part in graduate seminars and may find part-time professional employment on faculty research projects. The Department of Humanities is mainly concerned with undergraduate education and offers a number of undergraduate degree programs. Through Course XXI, students may major in one of the humanistic disciplines (e.g., history, literature, anthropology, foreign languages, writing, music) or combine the study of any of these disciplines with a science or an engineering field in one of the unique dual-degree programs (Course XXI-E and XXI-S) offered by the Institute.

In addition, Course XXI offers a major jointly administered by the Department of Humanities and the Program in Science, Technology, and Society. Undergraduates may indeed, once they have fulfilled the Institute Science Requirements, devote all of their time to the humanities and social sciences and acquire a solid foundation for advanced work in any of the disciplines represented in the School. The student of the humanities or social sciences who wishes to deepen his or her fluency in science or engineering, perhaps with an eye to a career in those fields, will also find a great deal of freedom (i.e., free elective time) to do so. Minor programs in the Humanities, Arts, and Social Sciences are also available and are described in each departmental section in this chapter.

A chief concern of the School in undergraduate education has long been the provision of subjects to fulfill the purposes of the Institute Requirement in the Humanities, Arts, and Social Sciences. The School of Architecture and Planning offers some subjects that satisfy the requirement, but the great majority are provided by the School of Humanities and Social Science. The object of the requirement, broadly stated, is to ensure that every undergraduate at MIT is exposed to a wide range of cultural and intellectual influences. MIT seeks to offer much the same range of subjects as a first-rate liberal arts college, in addition to the special offerings made possible by well-developed graduate and research programs. There are numerous offerings in English and foreign literatures, foreign languages, archaeology and anthropology, history, music, drama, writing, and a wide variety of other subjects. The range of options is constantly changing, as new activities evolve at MIT and as student interests change.

The School is particularly anxious to encourage students equally concerned with the sciences and technology and with the humanities and social sciences to come to MIT. We are persuaded that modern society has been unduly constricted intellectually by the tradition that has tended to segregate scientific and humanistic education. Undergraduate education at MIT is moving increasingly in the direction already being taken by research, and is placing a growing emphasis on collaborative endeavors which connect the sciences, engineering, and humanities.

To stress this new development is not to imply that MIT emphasizes science and technology in all its offerings in the humanities and social sciences. Ample room remains for more or less conventional majors in economics, political science, philosophy, history, literature, foreign languages, anthropology, writing, and music. Students continue to demand the best in the humanities and social sciences as they demand the best in science and engineering. However, the emphasis continues to be on making MIT undergraduate education something quite distinctive.

Laboratories and Centers administered within the School include the following:

Center for International Studies

Center for Materials Research in Archaeology and Ethnology

Statistics Center

Detailed descriptions of these centers can be found in Chapter VI of this catalog.

Special Interdisciplinary Programs in Humanities and Social Science

The School offers a number of undergraduate academic programs embracing several disciplines. In general, these programs are staffed collaboratively by faculty members from various departments and fields in the School of Humanities and Social Science and, in some cases, from the Institute's other Schools as well.

Concentrations within the Humanities, Arts, and Social Sciences Requirement are available in all of these areas, degree programs in some of them.

Full information on subjects offered, names of participating faculty, and specific concentration and major requirements in these programs may be obtained from the individual program Coordinator or from the Humanities, Arts, and Social Sciences Information Office, Room 14N-408, (617) 253-4441. The lists of subjects also appear in the *Guide to the Humanities, Arts, and Social Sciences.*

Brief descriptions of the programs follow.

American Studies

American Studies at MIT offers students the opportunity to organize subjects from various fields (e.g., History, Anthropology/Archaeology, Literature, Political Science, Music, Art and Architecture, and Urban Studies) into personally constructed interdisciplinary programs as a way of gaining an integrated understanding of American society and culture.

American Studies is a field of concentration; it is also available as the humanities part of a **joint degree program** (Course XXI-E or XXI-S), or as a full major by special arrangement. American Studies majors work out a coherent program of study with an advisor, usually including two subjects each in Literature and History, although variations are possible. Major programs can center on a particular interest (e.g., law in America, contemporary American politics, the 19th-century American novel) or aim more broadly at a comprehensive knowledge of various aspects of America. See Degree Program Requirements under the Department of Humanities.

Coordinator of American Studies for 1988-89 is Professor Arthur D. Kaledin, Room E51-122, 253-4144.

Ancient and Medieval Studies

Through a wide variety of subjects drawn from a number of disciplines, this program provides a curricular framework for exploring topics in ancient and medieval studies ranging from the history of ideas and institutions to that of material artifacts, literature, and certain branches of the original languages. The chronological span of the program includes the 6,500 years between 5000 BC and 1500 AD. Subjects are drawn from Literature, Foreign Languages and Literatures, History, and Anthropology/Archaeology. Ancient and Medieval Studies is available as a field of concentration.

The goal of this program is to develop knowledge and understanding of the more distant past for itself, in its uniqueness, and to serve as an object for modern questions and methods of inquiry. Emphasis is placed on the structure of institutions and social systems, and on relationships among the social order and learned traditions, values, ideologies, and ideas. Ancient and medieval studies derive a special interest from the fact that the record is so full and various and that much of it is of exceptionally high quality in substance and form.

Coordinator of Ancient and Medieval Studies for 1988-89 is Professor Richard M. Douglas, Room E51-210A, 253-4445.

Drama Program

The Drama Program offers an opportunity for the serious study of dramatic literature based on practical experience acquired through the production of plays in the theatre. Students concentrating in drama are asked to divide their studies between subjects that explore the various forms and the traditional masterpieces of drama throughout the ages, from the Greeks to the present, and theatre or dance practicum subjects that involve direct participation in various aspects of actual productions mounted in the Kresge Little Theatre. The program is coordinated with the activities of the MIT Dramashop and the Dance Workshop, where students work and study with a professional staff that teaches directing, acting, choreography, dance aesthetics, scene and costume design, stage lighting, makeup arts, and general scenecraft.

For further information on a concentration in Drama and a list of the approximately 15 subjects that MIT offers in dramatic literature, theatre arts, and dance, please contact Dr. Robert N. Scanlan, Room W16-018, 253-2908, or the Humanities, Arts, and Social Sciences Information Office, 14N-408, 253-4441.

Film and Media Studies

The program in film and media offers MIT undergraduates an opportunity for interdisciplinary study of film, television, and other media of mass communications. The goal of the program is to develop an understanding of the historical, cultural, and artistic significance of film and other modern media.

The curriculum is broadly organized in three categories. The first is devoted exclusively to film and emphasizes the historical and artistic perspectives of the liberal arts. The second group is devoted primarily to television and mass communications and centers on the political, ideological, and policy-oriented perspectives of the social sciences. The third category — comparative studies in film and media — aims to combine social-scientific and humanistic perspectives and to compare contemporary forms of communication with their ancestors in older cultures and with other contemporary technologies.

Many of the subjects that comprise the core curriculum make extensive use of such resources as the MIT Cable Television System, which telecasts films and specially prepared tapes in conjunction with particular subjects; the University Film Study Center, an archive containing primary film and video materials as well as books and periodicals devoted to film and media; and the Research Program on Communications Policy, which conducts seminars and research on the mass media. Many core subjects also exploit video technologies in the classroom and encourage students to use video playback systems in preparing for tests and essays.

Faculty drawn from the following fields regularly teach subjects in the core curriculum: Art and Architecture, Foreign Languages and Literatures, Literature, and Political Science.

The Director of Film and Media Studies for 1988-89 is Professor David Thorburn, Room 14N-335, 253-6950.

Integrated Studies Program

The Integrated Studies Program (ISP) is designed for students who seek to approach their education within the larger context of humanistic and social concerns. Presently designed as an option for freshmen, ISP will expand its activities to include upperclass students as well.

All ISP students are encouraged to participate in fall and spring humanities seminars designed to connect technology-related issues to literature, history, anthropology, the arts, philosophy, and ethics.

Freshmen attend the mainstream lectures in calculus, physics, and chemistry, but attend recitations populated exclusively by other ISP students. Upperclassmen attend regular lectures in their departments' required or recommended subjects, and are invited to join the ISP staff as tutors in freshman mathematics and science.

Further information about ISP can be found in Chapter III, or contact Professor Leon Trilling, 20C-113, 253-7407, or Anne Armitage, 20C-117, 253-4074.

Latin American Studies

The program in Latin American Studies offers MIT students the chance to explore interconnections among culture, society, and politics in a major Third World area. Its underlying purpose is to reveal the historical and contemporary forces that have shaped Latin American civilization and that delineate prospects and problems for future development, including the relationship to the United States and other parts of the industrial world. The subjects offered at MIT in Latin American Studies are drawn from various disciplines, primarily Foreign Languages and Literatures, History, Anthropology/Archaeology, and Political Science.

Latin American Studies is available as a concentration and also as the humanities part of a **joint degree program** (Course XXI-E or XXI-S). For the major, students must take at least one advanced subject conducted in Spanish (or Spanish III and IV). No more than four subjects can be from a single discipline; no more than two can focus on the Iberian peninsula. See Degree Program Requirements under the Department of Humanities.

Coordinator of Latin American Studies for 1988-89 is Professor Jonathan A. Fox, Room E53-365, 253-5327.

Program in Psychology

Psychology, the study of human mental life and behavior, is represented at MIT as a program in the School of Humanities and Social Sciences, and as a concentration within the undergraduate HASS requirement. Faculty and courses in psychology are found in many MIT departments, including Brain and Cognitive Sciences (IX), Management (XV), History (XXI), Architecture (IV), and STS. Students who wish to concentrate in psychology will

take a set of subjects from these departments, chosen in consultation with the Psychology Program's concentration officer (details are available at the HASS office).

Students who wish a more substantial education in the field may minor in Psychology. A minor involves six subjects starting with 9.00 Introduction to Psychology. Detailed information about the minor is found in the description of undergraduate study for Course IX, Department of Brain and Cognitive Sciences.

In addition to taking psychology subjects, undergraduates may take advantage of a wide range of research opportunities (generally via the UROP program). Students should ask the UROP coordinators for specific departments about projects currently available.

Psychology does not exist as a major at MIT. Interested students should consider majoring in Cognitive Science (Course IX). See the description under the Whitaker College of Health Sciences, Technology, and Management, or contact Professor Susan Carey, E10-030 253-5768, for further information about the Course IX major.

For other information about the Program in Psychology, contact Professor Jeremy Wolfe, E10-137, 253-4875.

Russian Studies

Russian Studies is an undergraduate program of analytical, historical, and evaluative subjects about people with a tradition and form of life different from the American in ways that are sometimes complementary, sometimes competitive. With a focus on both the society and the culture of a significant area of the world, this interdisciplinary and interdepartmental program is designed to make possible concrete exploration of important concerns of modern humanity. These include tradition and radicalism; rural versus urban life; the place of the imagination in historical change; industrialization, technology, and the expressivistic modern sensibility; and humanism and terror. The subjects in Russian Studies are drawn primarily from History, Literature, Political Science, and Russian. Readings and classes in all subjects are in English.

Russian Studies may be taken as a concentration or as the humanities part of a **joint degree program** (Course XXI-E or Course XXI-S). The major includes at least two subjects each in Russian society and Russian culture.

Students may arrange Russian language credits within the major program and use the language in certain subjects. See Degree Program Requirements under the Department of Humanities.

Coordinator of Russian Studies for 1988-89 is Professor Catherine Chvany, Room 14N-311, 253-6341.

Women's Studies Program

Women's Studies involves a recognition of the importance of gender as an analytic category in traditional academic disciplines. Subjects offered in this program provide students with an alternative way to think about fields of study, reading back into those fields the social, historical, and cultural experiences and contributions of women. A Women's Studies perspective adds an important and long-neglected dimension to traditional humanistic, scientific, and social scientific disciplines by reconstructing standards for theory and methodology in fields as diverse as biology, psychology, and literature.

Women's Studies subjects are designed to make women's reality visible whatever the area of study. They often examine sex roles and gender identity for men and for women at the individual level, at different times, and in different societies. They ask whether or not there are cultural universals in the definition of gender. The curriculum includes two core subjects, Introduction to Women's Studies and Contemporary Issues in Women's Studies, and a selection of subjects from many departments at the Institute, listed in the Special Programs section of Chapter VIII. A **major departure** can be organized by special arrangement. Women's Studies also offers a minor program and a concentration.

The program is described in greater detail in Chapter III. Further information may be obtained from Professor Isabelle de Courtivron or Barbara Schulman, Room 14E-316, 253-8844.

The **Minor Program** in Women's Studies enables students to progress from a broad interdisciplinary introduction to the field to discipline-specific subjects and specialized seminars. The Women's Studies Minor encourages students to consider gender as a category of analysis in traditional scholarly inquiry.

The Minor Program in Women's Studies consists of six subjects arranged into three levels of study as shown in the next column.

TIER I: One subject:

SP 401	Introduction to Women's Studies

TIER II: Four subjects from the Women's Studies curriculum in no less than three of the following four areas:

1) Literature
2) History
3) Anthropology/Sociology/Economics
4) Biology/Psychology

TIER III: One subject:

SP 402	Contemporary Issues in Women's Studies
or	
SP 452J	Current Issues in the Women's Movement

Office of the Dean

Ann Fetter Friedlaender, Ph.D.
Professor of Economics and Civil Engineering
Dean

Philip S. Khoury, Ph.D.
Associate Professor of History
Associate Dean

Douglas W. Pfeiffer, M.B.A.
Assistant Dean for Finance and Administration

Barbara G. Stowe, B.A.
Assistant Dean for Development

Susan Mannett
Assistant to the Dean for Personnel

Ruth V. Spear, B.A.
Coordinator, Humanities, Arts, and Social Sciences Office

School Faculty and Staff Without Departmental Affiliation

Martin Dyck, Ph.D.
Professor of German and Literature, Emeritus

Ruth Perry, Ph.D.
Professor of Literature and Women's Studies

Robert N. Scanlan, Ph.D.
Lecturer in Drama and Theatre Arts

Beth Soll, B.S.
Senior Lecturer in Dance

William Nash Locke, Ph.D.
Professor of Modern Languages, Emeritus
Director of Libraries, Emeritus

Department of Economics

Richard Samuel Eckaus, Ph.D.
Ford International Professor of Economics
Head of the Department

Peter Temin, Ph.D.
Professor of Economics
Associate Head of the Department

Professors

Olivier Jean Blanchard, Ph.D.
Professor of Economics

Peter Arthur Diamond, Ph.D.
Professor of Economics

Rudiger Dornbusch, Ph.D.
Ford International Professor of Economics

Henry Stuart Farber, Ph.D.
Professor of Economics

Stanley Fischer, Ph.D.
Professor of Economics
(On leave)

Franklin Marvin Fisher, Ph.D.
Professor of Economics
(On leave, fall)

Ann Fetter Friedlaender, Ph.D.
Professor of Economics and Civil Engineering
Dean, School of Humanities and Social Science

Drew Douglas Fudenberg, Ph.D.
Professor of Economics

Oliver D'Arcy Hart, Ph.D.
Professor of Economics
(On leave)

Jerry Allen Hausman, D.Phil.
Professor of Economics

Paul Lewis Joskow, Ph.D.
Professor of Economics

Paul Robin Krugman, Ph.D.
Professor of Economics

Daniel Little McFadden, Ph.D.
Elizabeth and James R. Killian Class of 1926 Professor
Professor of Economics

Michael Joseph Piore, Ph.D.
Professor of Economics and Management

James Michael Poterba, D.Phil.
Professor of Economics

Jerome Rothenberg, Ph.D.
Professor of Economics

Richard Lee Schmalensee, Ph.D.
Professor of Management and Economics

Abraham J. Siegel, Ph.D.
Howard W. Johnson Professor of Management

Robert Merton Solow, Ph.D., LL.D., D.L.H.
Institute Professor
Professor of Economics

Lance Jerome Taylor, Ph.D.
Professor of Economics

Lester Carl Thurow, Ph.D.
Gordon Y Billard Professor of Economics and Management
Dean, Sloan School of Management

Jean Tirole, Ph.D.
Professor of Economics
(On leave)

Martin Lawrence Weitzman, Ph.D.
Mitsui Professor in Problems of Contemporary Technology
Professor of Economics

Associate Professors

Jeffrey Earl Harris, M.D., Ph.D.
Associate Professor of Economics
(On leave)

Garth Saloner, Ph.D.
Associate Professor of Applied Economics and Economics

William Cody Wheaton, Ph.D.
Associate Professor of Economics and Urban Studies

Assistant Professors

Philippe M. Aghion, Ph.D.
Assistant Professor of Economics

Roland Benabou, Ph.D.
Assistant Professor of Economics

Robert Gibbons, Ph.D.
Assistant Professor of Economics
(On leave)

Danny Quah, Ph.D.
Assistant Professor of Economics

Andrea L. Shepard, Ph.D.
Assistant Professor of Economics

Jeffrey M. Wooldridge, Ph.D.
Assistant Professor of Economics

Visiting Professors

Mathias Dewatripont, Ph.D.
Assistant Professor of Economics

Michael Woodford, Ph.D.
Assistant Professor of Economics
(Fall)

Administrative Officer

Pamela Phillips, M.B.A.

Professors Emeriti

Morris Albert Adelman, Ph.D.
Professor of Economics, Emeritus

Sidney Stuart Alexander, Ph.D.
Professor of Economics and Management, Emeritus

Robert Lyle Bishop, Ph.D.
Professor of Economics, Emeritus

Edgar Cary Brown, Ph.D.
Professor of Economics, Emeritus

Evsey David Domar, Ph.D.
Ford International Professor of Economics, Emeritus

Harold Adolph Freeman, S.B.
Professor of Statistics, Emeritus

Everett Einar Hagen, Ph.D.
Professor of Economics and Political Science, Emeritus

Charles Poor Kindleberger, Ph.D., D.H.C.
Ford International Professor of Economics, Emeritus

Franco Modigliani, D.Jur., D.Soc.Sci., LL.D.
Institute Professor
Professor of Economics and Finance

Charles Andrew Myers, Ph.D.
Professor of Industrial Relations
Sloan Fellows Professor of Management, Emeritus
Senior Lecturer

Paul Pigors, Ph.D.
Professor of Industrial Relations, Emeritus

Paul Anthony Samuelson, Ph.D., LL.D., D.Litt., Sc.D.
Institute Professor
Professor of Economics, Emeritus
Gordon Y Billard Fellow

Department of Economics

(Course 14)

Undergraduate Study

Economics is the study of all those aspects of individual and social activities related to the choice, production, distribution, and consumption of goods and services. In relation to these decisions, economics is concerned with the behavior and interaction of individuals, private firms, and other institutions and government agencies. Thus, economics contributes to the understanding of many important social problems: changes in efficiency and productivity, fluctuations in the overall levels of economic activity and employment, inflation, the effects of government deficits, the growth and decline of industries, changes in foreign exchange rates, increases in international indebtedness, and the behavior of the centrally planned and less developed countries.

Courses are offered in the major areas of economics: theoretical and applied analysis at the levels of the individual consumer, the firm, and the industry, as well as aggregate economic activity, industrial organization and health economics, econometrics, public finance, urban economics, labor economics and industrial relations, comparative economic systems, international trade and finance, economic history and economic development.

The objective of the **Minor Program** is to extend the understanding of economic issues beyond the level of the concentration. This is done through specialized analytical subjects and elective subjects that provide an extensive treatment of economic issues in particular areas.

The Minor Program in Economics consists of six subjects arranged into three levels of study as follows:

TIER I: Three subjects:

14.01 Principles of Microeconomics
14.02 Principles of Macroeconomics
and either
14.30 Introduction to Statistical Method in Economics
or
18.05 Introduction to Probability and Statistics

TIER II: One subject from the following three:

14.03 Applied Microeconomics
14.04 Intermediate Microeconomic Theory
14.06 Intermediate Macroeconomic Theory

TIER III: Two subjects:

Two elective undergraduate subjects chosen from the fields of applied economics.

In addition to its broad undergraduate program, the Department offers a graduate program leading to the Ph.D. in economics. The introduction to the School of Humanities and Social Science found earlier in this chapter describes the Department in the context of the School and of MIT.

Bachelor of Science in Economics Course XIV

The Course leading to the Bachelor of Science in Economics combines training in technical economics with opportunities for a broad and balanced undergraduate education. Students may choose from a diversified group of undergraduate subjects and are encouraged to engage in independent research.

The aims of the undergraduate degree program are threefold: 1) to give students a firm grounding in modern economic theory and a basic understanding of economic processes; 2) to provide a descriptive knowledge of the US and world economies; and 3) to develop in students the capabilities for quantitative analysis and independent thought. These aims correspond roughly to the requirements in the Course XIV program of theory, electives, statistics and econometrics, and research.

The requirements allow substantial freedom for students in designing individual programs within economics and balancing the programs with subjects in other disciplines. The large amount of unrestricted elective time encourages students to shape programs close to their own needs and interests. Students may select programs that concentrate on economics and other social sciences or may combine economics with other fields. They may emphasize the relation of economics and technology by choosing their free electives in engineering and science. Or they may combine their studies in economics with courses in history and the other humanities.

The successful completion of the degree program prepares students for further study in economics or for careers in business administration and finance, industrial relations, law and related fields, and government.

Although there are several satisfactory alternative course sequences, students who by the end of their second year have taken 14.01 Principles of Microeconomics, and 14.02 Principles of Macroeconomics, can follow a program that permits considerable depth in electives in their third and fourth years. 14.04 Intermediate Microeconomics, 14.06 Intermediate Macroeconomics, and 14.30 Introduction to Statistical Methods in Economics, and 14.31 Econometrics, can be completed in the third year. This program satisfies the prerequisites for all subjects and prepares students for research on their thesis and in other elective subjects in their fourth year.

The Department specifies one science distribution subject and one laboratory subject, and strongly recommends that all students take an additional subject in computer techniques and, if professionally interested in economics, further work in mathematics.

Bachelor of Science in Economics Course XIV

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [3 subjects can be satisfied by subjects in the Departmental Program][1]	8
Science Distribution Requirement [1 subject can be satisfied by 14.30 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 14.31 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	81
14.01 Principles of Microeconomics, 9	
14.02 Principles of Macroeconomics, 9	
14.04 Intermediate Microeconomic Theory, 12; 14.01	
14.06 Intermediate Macroeconomic Theory, 12; 14.02	
14.30 Introduction to Statistical Method in Economics[2], 12; 18.02	
14.31 Econometrics, 12; 14.30	
14.39 Undergraduate Thesis Seminar[3], 6; 14.04, 14.06, 14.31	
Thesis (9 units)	
Restricted Electives:	45-60[4]
Elective subjects in economics	
Units in Departmental Program that also satisfy the General Institute Requirements	(51-60)[4]
Unrestricted Electives	99-105[4]
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

1
No more than 27 units in Economics, excluding the required subjects, may be used for the Humanities, Arts, and Social Sciences Requirement.
2
Or an approved alternative in statistics.
3
14 UR Undergraduate Research (Arr. units) approved as to content may be substituted for 14.39.
4
The precise number will depend on the units of courses chosen.

Bachelor of Science in Economics Course XIV

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program[1], plus appropriate subjects totaling	45
Science Distribution Requirement can be satisfied by 14.30 in the Departmental Program, plus appropriate subjects totaling	24
Laboratory Requirement can be satisfied by 14.31 in the Departmental Program.	

Departmental Program	
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	81
14.01 Principles of Microeconomics, 9	
14.02 Principles of Macroeconomics, 9	
14.04 Intermediate Microeconomic Theory, 12; 14.01	
14.06 Intermediate Macroeconomic Theory, 12; 14.02	
14.30 Introduction to Statistical Method in Economics[2], 12; 18.02	
14.31 Econometrics, 12; 14.30	
14.39 Undergraduate Thesis Seminar[3], 6; 14.04, 14.06, 14.31	
Thesis (9 units)	
Restricted Electives:	45
Elective subjects in economics	
Unrestricted Electives	105
Total Units Required for the S.B. Degree	360

1
No more than 27 units in Economics, excluding the required subjects, may be used for the Humanities, Arts, and Social Sciences Requirement.
2
Or an approved alternative in statistics.
3
14 UR Undergraduate Research (Arr. units) approved as to content may be substituted for 14.39.

Graduate Study

Entrance Requirements for Graduate Study

The Department specifies the following prerequisites for graduate study in economics: one full year of college mathematics, including at least one term of calculus; one full year of college work in science; at least six term subjects in English, history, and other humanities or social science subjects (not in the candidate's own professional field) equivalent to those included in the undergraduate curriculum at MIT; and an appreciable number of professional subjects in economics for those qualified students who have majored in fields other than economics. Applicants for admission who have deficiencies in entrance requirements should consult with the Department about programs to remove such deficits.

Master of Science in Economics

Under special circumstances, admission may be granted to candidates seeking the Master of Science degree. The general requirements for the S.M. are given in Chapter IV.

Doctor of Philosophy

A candidate for the doctorate must 1) demonstrate a mastery of five fields of study, one of which is economic theory, including both microeconomics and macroeconomics; 2) achieve a specified level of competence in economic history and econometrics; 3) submit and defend a dissertation that represents a contribution to knowledge; and 4) be in residence for a minimum of two years. Three of the five fields, including economic theory, are covered by the written General Examination. Two minor fields may each be satisfied by one year of course work. The four major and minor elective fields may be chosen from advanced economic theory, comparative economic systems, econometrics, economic development, economic history, finance, fiscal economics, human resources and the distribution of income and wealth, industrial organization, international economics, labor economics, monetary economics, and urban economics.

There is no required minimum number of graduate subjects in the Department. However, candidates ordinarily need two full academic years of study to prepare adequately for the General Examinations and to meet the other pre-thesis requirements. The doctoral thesis must be written in residence. It typically requires two years of research.

The Department has no general foreign language requirements. When a foreign language is essential for full access to the literature in a field of major interest (for example, European economic history, Russian economics) or to thesis research, a language requirement is imposed by the Department upon the recommendation of the thesis supervisor or the Graduate Registration Officer. Such a requirement is administered by the Department of Humanities and can be met by satisfactory course work at other schools or at MIT, or by examination.

Students interested in developing professional competence in economics and urban studies may elect an interdepartmental program in the Departments of Economics and Urban Studies and Planning, which is described in more detail in Chapter VI.

Teaching and Research Assistantships

A limited number of students are supported by scholarship and fellowship grants as well as by teaching and research assistantships. Typically, the assistantships are available only to students who have passed their general examinations, but in special circumstances, research assistantships may be held by second-year students.

Inquiries

Additional information concerning academic programs in the Department, admissions, and financial aid may be obtained by writing to Professor R. S. Eckaus, E52-373A, MIT, 50 Memorial Drive, Cambridge, Massachusetts 02139, (617) 253-3361.

Department of Humanities

(Course 21)

Anthropology/Archaeology
Foreign Languages and Literatures
History
Literature
Music
The Writing Program

The introduction to the School of Humanities and Social Science found earlier in this chapter describes the Department in the larger context of the School and of MIT.

The Department of Humanities consists of a number of autonomous sections and programs, each with its own headquarters. There are currently six such units: 1) Anthropology/Archaeology, 2) Foreign Languages and Literatures, 3) History, 4) Literature, 5) Music, and 6) Writing.

All the programs in the Humanities provide subjects that help to satisfy the Institute Requirement in Humanities, Arts, and Social Sciences. **Undergraduate degree programs** are available in Course XXI, either in combination with Engineering or Science curricula (XXI-E, XXI-S) or as full majors (XXI), described later in this section. Students interested in any of these degree programs should consult an advisor in the field, and individual section and program offices.

Anthropology/Archaeology

James Howe, Ph.D.
Associate Professor of Anthropology
Program Head

Martin Diskin, Ph.D.
Professor of Anthropology

Jean Elizabeth Jackson, Ph.D.
Professor of Anthropology

Heather Nan Lechtman, M.A.
Professor of Archaeology and Ancient Technology
Director, Center for Materials Research in Archaeology and Ethnology

Arthur Steinberg, Ph.D.
Associate Professor of Archaeology

Lisa Beth Rofel, Ph.D.
Assistant Professor of Anthropology and Science, Technology, and Society
(On leave)

Jonathan Wylie, Ph.D.
Assistant Professor of Anthropology
(Visiting)

Alison Salisbury, B.A.
Program Coordinator

Cyril Stanley Smith, Sc.D.
Institute Professor, Emeritus
Professor of the History of Science and Technology, Emeritus
Professor of Metallurgy, Emeritus

Anthropology/Archaeology

Anthropology studies humankind from a comparative perspective that emphasizes the diversity of human behavior and the importance of culture in explaining that diversity. While the discipline encompasses the biological nature of our species and the material aspects of human adaptation, it takes as fundamental the idea that we respond to nature and natural forces in large part through culture. Anthropology, then, is the study of human beings as cultural animals. Archaeology, one of its principal branches, uses material remains to study cultures, often over long time periods. Cultural anthropology draws its data from the direct study of contemporary peoples living in a wide variety of circumstances, from peasant villagers and tropical forest hunters and gatherers, to urban populations in modern societies.

The Anthropology/Archaeology Program at MIT offers students a broad exposure to the discipline as well as an anthropological perspective on problems and issues relevant to other fields in the humanities, social sciences, and engineering. It also provides more intensive introductions to areas of faculty specialization, which include social and political organization, economics and human ecology, religion and symbolism, paleobotany, technology and materials science, and the anthropology of art and scientific research. Geographical specializations include ancient and modern cultures of the Americas, ancient civilizations of the Mediterranean and Near East, and modern China and the United States.

The scientific study of technologies and materials from ancient and contemporary non-western societies forms a special field of research and teaching for the Anthropology/Archaeology Program. MIT archaeologists, together with colleagues in the Department of Materials Science and Engineering and with anthropologists and archaeologists from six museums and universities in the Boston area, founded the Center for Materials Research in Archaeology and Ethnology (CMRAE). The center, which is directed by MIT Anthropology/Archaeology faculty, provides a focus for research, teaching, and graduate training in this field, and is described in further detail in Chapter VI. Students may participate in research projects by arrangement with the appropriate faculty members.

The Anthropology/Archaeology curriculum is divided into five groups that show the breadth of the field, with particular emphases. Introductory subjects (21.50-21.506) encompass broad topics such as human evolution and archaeological methods. Social Anthropology subjects (21.511-21.531J) deal with a wide range of concerns about religion and sociopolitical organization in modern communities (mostly in Latin America and our own society). The subjects in the section on Technology and Cultural Context (21.534J-21.543J) focus on various early and modern technologies and how they relate to their cultural settings. The Archaeology subjects (21.550-21.561) cover the ancient cultural sequences in certain regions, as well as topics such as empires and cities viewed in a cross-cultural perspective. The subjects given by CMRAE have prerequisites and are open only to graduate students and qualified upperclass students; most of the other offerings do not carry prerequisite requirements.

Students taking a concentration in anthropology are advised to choose a mix of subjects in archaeology and cultural anthropology with help from the program's concentration advisor. Anthropology subjects qualify for several interdisciplinary concentrations, including Women's Studies, Latin American Studies, and "Technology, Culture, and Development."

The **Minor Program** in Anthropology/Archaeology consists of six subjects arranged into three tiers as shown below. Students will create individual programs focusing in Anthropology or Archaeology with the help of the Minor Advisor to ensure they gain a coherent introduction to the methods, approaches, and some of the results of the discipline.

TIER I: Two subjects:

One subject in cultural anthropology:
21.50 Introduction to Anthropology
and
One archaeological subject chosen from:
21.503 Introduction to Archaeology: Paths to Civilization
21.504 Approaches to Archaeology

TIER II: Three subjects from the following areas:

1) Social Anthropology (except 21.514)
2) Technology and Cultural Context (except 21.536J)
3) Archaeology: Regional and Topical
4) Special Topics

TIER III: One subject:

21.510 Seminar in Anthropological Method and Theory

Degree programs in Anthropology/Archaeology include joint majors in combination with a field of engineering or science (Course XXI-E, Course XXI-S), as well as a more intensive full major in Anthropology/Archaeology (Course XXI). See Degree Program Requirements. Subject 21.50 is strongly recommended as a preliminary subject for these degree programs (in addition to the required program of studies).

Subjects in Anthropology/Archaeology are numbered 21.50 through 21.599 in Chapter VIII. Further information on subjects and programs may be obtained from the Anthropology/Archaeology Program Office, Room 20B-131, (617) 253-3065.

Foreign Languages and Literatures

(To be appointed)
Section Head

Catherine Vakar Chvany, Ph.D.
Professor of Russian

James Wesley Harris, Ph.D.
Professor of Spanish and Linguistics
(On leave, fall)

Robert Emmet Jones, Ph.D.
Professor of French and Humanities

Claire J. Kramsch, Agrégation
Professor of Foreign Language Acquisition

Isabelle de Courtivron, Ph.D.
Associate Professor of French

Suzanne Flynn, Ph.D.
Associate Professor of Second Language Acquisition

Elizabeth Garrels, Ph.D.
Associate Professor of Spanish

Michael Geisler, Ph.D.
Associate Professor of German

Margery Resnick, Ph.D.
Associate Professor of Spanish

Edward Baron Turk, Ph.D.
Associate Professor of French

Edith Waldstein, Ph.D.
Assistant Professor of German

Patricia Baudoin, Ph.D.
Lecturer in French

Kathryn Crecelius, Ph.D.
Lecturer in French

Ellen Crocker, M.A.
Lecturer in German

Gilberte Furstenberg, Agrégation
Lecturer in French

Michael Knittel, Ph.D.
Lecturer in German

Evelyn Lilienfeld, M.A.
Lecturer in Spanish

Douglas Morgenstern, M.A.
Lecturer in Spanish

Elena Semeka-Pankratova, Ph.D.
Lecturer in Russian

Ruth Trometer
Director of the Language Laboratory

Margaret Zaroodny Freeman, S.M.
Associate Professor of Russian, Emerita

Foreign Languages and Literatures

The Foreign Languages and Literatures Section offers a variety of programs. There are subject sequences in French, German, Russian, Spanish language and literature taught in the original; a subject sequence on literature taught in English translation; a comprehensive program in English as a second language; and a two-year language sequence in Japanese.

The study of a foreign language broadens one's cultural perspective, sharpens awareness of use and meaning of words in our own language, and increases one's range of expression. At MIT, students have the opportunity to bring their knowledge of a foreign language to the level at which they can not only speak fluently, but also read with pleasure and critical awareness. If preserved through use, these skills constitute an intellectual and personal resource throughout a lifetime, and can be an important asset for those pursuing careers with international dimensions.

The Foreign Languages and Literatures curriculum is arranged in three tiers: 1) Fundamental language subjects familiarize students with the principles of the language in both its spoken and written forms, and introduce them to the culture of the country where the language is spoken. Levels III and IV language subjects provide for review and refinement of grammar, study of more difficult reading matter with cultural and literary content, and include compositions and discussions in the foreign language. 2) Intermediate subjects in language, literature, and civilization are conducted in the foreign language. They introduce students to the form and content of foreign literatures and of foreign cultures and societies. These courses also offer the opportunity to develop more refined communication skills in the language. 3) Advanced subjects in literature and civilization, conducted in the foreign language, encourage students to explore in depth specific literary genres, authors, and periods in the literary and cultural history of the countries where the language is spoken.

Under the rubric "Literature in Translation," offerings make available in English various modes of intercultural discourse. These include great works of foreign literature, foreign film, and works by women writers from many countries. Under the heading "Studies in Language," courses aim to sensitize students to the nature and structure of language and communication. "English as a Second Language" subjects offer a solid basis of oral and written skills in English to students whose native language is other than English.

Concentrations are available in: 1) a given language, 2) language and literature, 3) literature and culture only, 4) the nature of language, and 5) world literature in translation. Concentrations should be arranged on an individual basis in consultation with a designated advisor in each language group.

The **Minor Programs** in French, German, Russian, and Spanish lead students who have already reached an intermediate level of proficiency into a more advanced study of the language, literature, and culture. **Note:** Basic language subjects do not count toward the minor.

The **Minor Program in French** consists of six subjects arranged into three levels of study as follows:

TIER I: One subject:

21.204 French IV

TIER II: Two or three subjects from the French Intermediate Subjects in Language, Literature, and Civilization listing: 21.207-21.212

TIER III: Two or three subjects from the French Advanced Subjects in Literature and Civilization listing: 21.213-21.228

The **Minor Program in German** consists of six subjects arranged into three levels of study as follows:

TIER I: One subject:

21.234 German IV

TIER II: Two or three subjects from the following: 21.237 - 21.239

TIER III: Two or three subjects from the following: 21.240 - 21.244, 21.306

The **Minor Program in Russian** consists of six subjects arranged into three levels of study as follows:

TIER I: One subject:

21.264 Russian IV

TIER II: Two subjects:

21.265 Advanced Russian Conversation and Composition
21.267 Modes and Styles of Russian Storytelling

TIER III: Three subjects from the following: 21.268 -21.271, 21.314 - 21.318

The **Minor Program in Spanish** consists of six subjects arranged into three levels of study as follows:

TIER I: One subject:

21.278 Spanish IV

TIER II: Two or three subjects from the Spanish Intermediate Subjects in Language, Literature, and Culture listing: 21.281 - 21.285

TIER III: Two or three subjects from the Spanish Advanced Subjects in Literature and Culture listing: 21.286 - 21.293

Degree programs are offered in French, German, Russian, and Spanish, and include joint majors in combination with a field of engineering or science (Course XXI-E, Course XXI-S), as well as a more intensive full major (Course XXI). See Degree Program Requirements.

Proficiency in a foreign language is a prerequisite for election to Phi Beta Kappa.

Subjects in Foreign Languages and Literatures, both in the original and in translation, are numbered 21.201 through 21.349. Further information on subjects and programs may be obtained from the Foreign Languages and Literatures Section Office, Room 14N-207, (617) 253-4771.

History

Richard Mateer Douglas, Ph.D.
Professor of History
Section Head

Robert Michael Fogelson, Ph.D.
Professor of History and
Urban Studies

Loren Graham, Ph.D.
Professor of the History of
Science
(On leave, fall)

Robert Ellsworth MacMaster, Ph.D.
Professor of History and Literature

Pauline Maier, Ph.D.
Professor of History
(On leave)

Bruce Mazlish, Ph.D.
Professor of History
Thomas Melroy Professor of Rhetoric

Harald Anton Thrap Olsen Reiche, Ph.D.
Professor of Classics and Philosophy

Merritt Roe Smith, Ph.D.
Professor of the History of
Technology
(On leave, spring)

Arthur Daniel Kaledin, Ph.D.
Associate Professor of History and
American Studies

Philip S. Khoury, Ph.D.
Associate Professor of History
Associate Dean, School of Humanities
and Social Science
(On leave)

Michael E. McGerr, Ph.D.
Associate Professor of History
(On leave, fall)

Peter Cushing Perdue, Ph.D.
Associate Professor of History

David Bird Ralston, Ph.D.
Associate Professor of History

William Braasch Watson, Ph.D.
Associate Professor of History

Sarah J. Deutsch, Ph.D.
Cecil and Ida Green Career
Development Assistant Professor
of History
(On leave)

Douglas J. Forsyth, Ph.D.
Assistant Professor of History

Robin Wallace Kilson, Ph.D.
Assistant Professor of History

Ellen Fitzpatrick, Ph.D.
Assistant Professor of History
(Visiting)

Hasan Kayali, Ph.D.
Assistant Professor of History
(Visiting)

June Namias, Ph.D.
Lecturer
(Visiting)

Howard Russell Bartlett, B.S., A.M.
Professor of History, Emeritus

Lynwood Silvester Bryant, A.M.
Professor of History and American
Studies, Emeritus

Thomas Henry Donald Mahoney, Ph.D.
Professor of History, Emeritus

Cyril Stanley Smith, Sc.D.
Institute Professor, Emeritus
Professor of the History of
Science and Technology, Emeritus
Professor of Metallurgy, Emeritus

History

History is the study of the recorded past. Since interest in the past is closely linked with a desire to understand the present, the history curriculum at MIT is tailored in part to put the modern world in historical perspective. Subjects explore the social, economic, and political transformations that shape the present; and efforts are made to suggest where traditional assumptions remain in present-day politics, society, and culture.

The curriculum seeks to encourage both an understanding of the human past and the development of skills necessary to express that knowledge effectively. Subject listings are divided into "Basic Fields," which provide surveys of scholarship organized by place and by topic or period, and "Special Subjects and Seminars," which are more limited in scope and specialized in focus.

The goal of the **Minor Program** is to lead the student from basic survey subjects into more focused studies of individual countries or periods of time, and to encourage thinking about broader analytical and comparative issues in historical study.

The Minor Program in History consists of six subjects arranged into three levels of study.

TIER I: At least one and no more than two survey or broad introductory subjects (HASS-D and HUM-D subjects)

TIER II: Three or four intermediate undergraduate elective subjects from the History Faculty curriculum

TIER III: One subject:

21.494 Seminar in Historical Methods

IN ADDITION: Students must satisfy a geographical requirement by taking at least one subject from each of the following: 1) America, 2) Europe, and 3) other areas of the world.

For a listing of available subjects in these areas, consult the History Office (E51-210) or the HASS Information Office (14N-408).

Degree programs in History include joint majors in combination with a field of engineering or science (Course XXI-E, Course XXI-S), as well as a more intensive full major in History (Course XXI). See Degree Program Requirements.

Subjects in History are numbered 21.350 through 21.498J in Chapter VIII. Further information on subjects and programs may be obtained from the History Faculty Office, Room E51-210, (617) 253-4965.

Literature

Alvin Charles Kibel, Ph.D.
Professor of Literature
Section Head

Peter Samuel Donaldson, Ph.D.
Professor of Literature

Albert Ramsdell Gurney, Jr., M.F.A.
Professor of Literature
(On leave, fall)

Louis Kampf, B.A.
Professor of Literature

Travis Rhodes Merritt, Ph.D.
Professor of Literature
Associate Dean for Student Affairs

Irene Tayler, Ph.D.
Professor of Literature

David Thorburn, Ph.D.
Professor of Literature

Cynthia Griffin Wolff, Ph.D.
Class of 1922 Professor of Literature
(On leave, fall)

David Martin Halperin, Ph.D.
Associate Professor of Literature

John Hildebidle, Ph.D.
Associate Professor of Literature

Amy Schraeger Lang, Ph.D.
Associate Professor of Literature
(On leave)

Stephen James Tapscott, Ph.D.
Associate Professor of Literature

Theoharis Constantine Theoharis, Ph.D.
Associate Professor of Literature

Rita Bettina Goldberg, Ph.D.
Assistant Professor of Literature
(On leave)

William J. Paul, Ph.D.
Associate Professor of Literature
(Visiting)

Monica L. Kearney, B.A.
Administrative Officer

William Chace Greene, M.A.
Professor of Literature, Emeritus

Theodore Wood, Jr., A.M.
Professor of Literature and
American Studies, Emeritus

Literature

The curriculum in literary studies at MIT aims to meet the interests of students who may be drawn to literary study only once or twice at the Institute, and to provide a rich program of study for students concentrating or majoring in literature. To an extent unusual in an undergraduate program, the curriculum lays emphasis on interdisciplinary approaches to literary texts and on theoretical, generic, and thematic subjects that range across geographical and historical boundaries.

Every literature subject offers significant opportunities for individual participation in class discussion and every subject is centrally committed to improving students' writing skills.

A *Supplement* to this catalogue, available from the Humanities Department offices, offers detailed descriptions of all literature subjects and includes specific information about required texts, writing assignments, and exams.

The Literature curriculum is arranged in three graduated categories or tiers: 1) "Introductory subjects" (21.001-21.010) focus on major literary texts grouped in broad historical and generic sequences, all carrying HASS Distribution credit. 2) "Intermediate subjects" (21.021-21.120) explore literary forms in greater depth and center on historical periods, literary themes, or genres. Most intermediate subjects carry a prerequisite of one prior literary course, but students are encouraged to consult individual instructors about prerequisites. 3) "Seminars" (21.171-21.177), restricted to students who have taken at least two previous subjects in literature, encourage a greater degree of independent work, such as oral reports and other special projects. Enrollment in seminars is strictly limited to a maximum of 12 students.

Concentrations in Literature are available in particular genres (e.g., poetry, drama, fiction) and in historical periods (e.g., ancient studies, 19th-century literature, modern and contemporary literature), as well as in popular culture, media and film studies, minority and ethnic studies, literary theory, and a range of national literatures.

The **Minor Program** aims to lay a foundation for advanced study and to enhance a student's appreciation of major narrative, poetic, and dramatic texts in relation to the cultures that produced and perpetuated them. To an extent unusual in undergraduate literary studies, the program lays emphasis upon interdisciplinary approaches and deals with texts ranging widely across linguistic and historical boundaries, as well as in diverse media.

The Minor Program in Literature consists of six subjects arranged into three levels of study as follows:

TIER I: At least one and no more than two subjects from 21.001 - 21.006, and 21.021

TIER II: Two or three subjects from 21.008 - 21.010, and 21.022 - 21.120, *but excluding* 21.033

TIER III: At least two subjects from the Literature Seminar subjects 21.171 - 21.177 and 21.033

IN ADDITION: At least two subjects constituting a Minor program must center on materials dating from before 1900.

The Literature Major. The Literature Faculty offers a variety of major programs, including joint majors in combination with curricula in Engineering or Science (Course XXI-E and Course XXI-S) as well as a more intensive full major program (Course XXI). For the full major, three seminars are required, as well as elective subjects in four of the following literary periods: 1) Ancient and Classical, 2) Medieval, 3) Renaissance, 4) 17th Century and Enlightenment, 5) 19th Century. The joint major requires two seminars and electives in three of these periods.

Subjects in Literature are numbered 21.001 through 21.199 in Chapter VIII. Further information on subjects and programs may be obtained from the Literature Faculty Office, Room 14N-305, (617) 253-3581.

Music and Theater Arts

David Mayer Epstein, Ph.D.
Professor of Music
Conductor of the MIT Symphony Orchestra
Section Head

Stephen Erdely, Ph.D.
Professor of Music

John Harbison, M.F.A.
Class of 1949 Professor of Music
(On leave)

Marcus Aurelius Thompson, D.M.A.
Professor of Music

Barry Lloyd Vercoe, D.M.A.
Professor of Media Arts and Sciences

Jeanne Shapiro Bamberger, M.A.
Associate Professor of Music

Lowell Edwin Lindgren, Ph.D.
Associate Professor of Music

Peter Child, Ph.D.
Assistant Professor of Music

Edward Cohen, M.A.
Senior Lecturer in Music

John Oliver, M.M.
Senior Lecturer in Music
Director, MIT Choral Society

Beth Soll, B.S.
Senior Lecturer in Dance

Pamela Wood Ambush, M.M.
Lecturer in Music

Betsy Burleigh, M.M.
Lecturer in Music
(On leave)

Mark Harvey, Ph.D.
Lecturer in Music

Martin Marks, M.A.
Lecturer in Music

Robert N. Scanlan, Ph.D.
Lecturer in Drama

Claudia Von Canon, M.A.
Lecturer in Music

Nancy Trudeau Cavanagh, B.A.
Administrative Officer

Klaus Liepmann
Professor of Music, Emeritus
Director of Music, Emeritus

Music

The Music Section offers a broad range of opportunities to experience and explore the field of music. A great variety of subjects is given, ranging from basic musicianship to computer music composition. They are arranged into five categories: Introductory, History/Literature, Theory/Composition, Performance, and Seminars/Tutorials. Most students begin with introductory subjects, but anyone with musical training is encouraged to begin with history/literature or theory/composition subjects, which constitute the nucleus of the program. Graduate credit is available for nearly all of the seminars and tutorials.

A symphony orchestra, choral groups, concert and jazz bands, and chamber music groups are an integral part of MIT's cultural life and of any student's musical development, no matter what technical proficiency they possess. Academic credit is available for some performance activities and instrumental study. Auditions are held at the beginning of each term.

The music faculty comprises professional composers, performers, historians, and theorists, whose individual interest in the confluence of history, theory, and performance is essential to our integrated music program.

The **Minor Program** is designed to give students a three-tiered exposure to three main branches of musical activity: performance, music literature, and music writing, with special adaptability to performers who wish to relate their practical work to classroom learning.

The Minor Program in Music consists of six subjects. Four subjects are at the introductory and intermediate level; the remaining two provide depth in one area of specialization.

TIER I: One subject from the following:

21.60	Introduction to Music
21.601	Fundamentals of Music
21.602	Basic Musicianship

TIER II: Three subjects, one from *each* of the following areas:

1) History/Literature: 21.621 - 21.636
2) Theory/Composition: 21.641
3) Performance (two terms): 21.651 - 21.658

(One year in the MIT Choral Society or Festival or Concert Jazz Band may be substituted for two terms of performance, but one additional subject will be required from area 1 or 2 in Tier III.)

TIER III: Two subjects from *one* of the following areas of specialization:

1) History/Literature: 21.611J, 21.621 - 21.636
2) Theory/Composition: 21.605, 21.615, 21.642 - 21.648, 21.671J - 21.686J
3) Performance (four terms): 21.651 - 21.658

A full **degree program** in music is available under Course XXI. For students interested in combining the study of engineering or science with humanities, joint majors in Course XXI-E and XXI-S provide the opportunity to pursue special interests. See Degree Program Requirements. The full major program includes four subjects in composition, three subjects in history and literature of music, and two subjects in performance. The joint major includes two subjects in each of these areas. Students wishing to enroll in any of these degree programs should consult the Major advisor in the Music Section no later than the beginning of their junior year.

Students who declare music as their major must have demonstrated proficiency in instrumental or vocal performance and in harmony and counterpoint (ordinarily by participating in a performance subject and by obtaining a good grade in 21.641, respectively). Seniors in the Full Major participate in a tutorial program in preparation for a thesis on an analytical or historical topic or an original composition. Those in the Joint Major take a Senior Music Seminar.

Subjects in Music are numbered 21.60 through 21.699 in Chapter VIII. Further information on subjects and programs may be obtained from the Music Section Office, Room 14N-434, (617) 253-3210.

The Writing Program

Kenneth R. Manning, Ph.D.
Professor of the History of Science
Program Head

Elzbieta Ettinger Chodakowska, Ph.D.
Professor of Writing

Alan P. Lightman, Ph.D.
Professor of Science and Writing

James Paradis, Ph.D.
Associate Professor of Technical Communication

Harriet Ritvo, Ph.D.
Associate Professor of Writing
(On leave, spring)

Marcel La Follette, Ph.D.
Assistant Professor of Writing

Marilyn Richardson, B.A.
Assistant Professor of Writing

Thomas Simmons, Ph.D.
Assistant Professor of Writing

Rosalind Williams, Ph.D.
Assistant Professor of Writing

Joe Haldeman, M.F.A.
Adjunct Professor of Fiction

Ilona Karmel, A.B.
Senior Lecturer in Writing
(On leave, spring)

Edward Barrett, Ph.D.
Lecturer in Writing

Steven Strang, Ph.D.
Lecturer in Writing

Rebecca Chamberlain, M.S.M.
Administrative Officer

Janet Murray, Ph.D.
Principal Research Scientist

Philip Alexander, M.S.
Research Associate

Robert Reynolds Rathbone, A.M.
Professor of Technical Communication, Emeritus

The Writing Program

The MIT Writing Program provides students the opportunity to experiment with writing as a craft and as a means of self-expression. The Program helps prepare students to communicate the results of their work forcefully and clearly to members of their professions and to larger audiences. All subjects in the Program emphasize the development of writing skills and strategies. Some subjects, including those at advanced levels and those offered for distribution, require substantial reading.

Subjects in the Program's three areas — 1) Exposition and Rhetoric, 2) Creative Writing, and 3) Science and Technical Communication — are taught at basic, intermediate, and advanced levels. All subjects require repeated writing and revision. In addition, manuscripts are typically discussed in workshops and receive the written commentary of the instructor. Students are encouraged to schedule private conferences with their instructors.

Concentrations in Writing establish a course of intensive study for prose, poetry, and fiction writers, or for engineers and scientists who expect writing to play a key role in their career development.

The **Minor Program** provides students with a structured opportunity to develop their expertise in one of the Program's three areas — exposition and rhetoric, creative writing, or science and technical communication — while also exploring offerings in the other areas.

The Minor Program in Writing consists of six subjects arranged into three levels of study as follows:

TIER I: One subject from the following:

21.730	Expository Writing
21.731	Writing and Experience
21.732	Introduction to Technical Communication

TIER II: Two or three subjects from among the Writing Intermediate subjects listing and 21.734

TIER III: Two or three subjects from among the Writing Advanced subjects listing and 21.798 (six units required)

IN ADDITION: Students must choose a sequence of courses reflecting one of three themes: (a) exposition and rhetoric, (b) creative writing, or (c) scientific and technical writing.

Degree Programs in Writing. The Course XXI-E and XXI-S Writing Major programs require a combination of subjects in science or engineering, an area of writing, and a related field of humanities, arts, or social sciences. The Course XXI full major in Writing offers students the opportunity to focus on a single area of the writing curriculum — exposition and rhetoric, creative writing, or science and technical writing — in conjunction with the study of a related field in the humanities, arts, or social sciences. The full major (XXI) in Science Journalism or Technical Communication is always accompanied by another degree program in engineering or science. See Degree Program Requirements. The degree requirements are flexible, and students must work out individual programs with their advisors.

The Writing Requirement. Students may satisfy Phase One of the writing requirement by earning a passing grade in any of several introductory writing subjects. Additional details may be obtained from the Office of the Writing Requirement (253-7909).

Writing Center. The MIT Writing Center offers free individual writing consultation on an appointment or drop-in basis to all members of the MIT community. In addition, the center gives mini-sessions each semester on a variety of writing topics, and also offers workshops for people for whom English is a second language. For further information, contact The Writing Center (253-3090).

Cooperative Writing Programs. The Science and Technical Communication staff of the Writing Program supports an interdepartmental program of writing instruction jointly with the undergraduate and graduate departments in the School of Engineering.

Subjects in Writing are numbered 21.730 through 21.799 in Chapter VIII. Further information on subjects and programs may be obtained from the Writing Program Office, Room 14E-303, (617) 253-7894.

Degree Program Requirements

Full, Joint, and Double-Degree Majoring

For students who wish to pursue their humanistic studies extensively and at an advanced level, two basic types of degree programs are available. The first, Course XXI, constitutes a **full** major in any one of seven fields of the humanities. The second, Course XXI-E or XXI-S, is a **joint** major combining work in humanities with work in engineering, science, or psychology. Further, a student pursuing either a **full** or **joint** major may obtain interdisciplinary competence on a larger scale by adding a separate major in any other Course of study available at MIT, as part of a **double-degree** arrangement. In fact, one version of the full major, that in Science, Technology, and Society (STS), may be taken only in conjunction with another degree program in Engineering or Science. Descriptions and specifications for full and joint major programs follow.

Bachelor of Science in Humanities Course XXI

This program provides a **full** major in any of the following fields:

Anthropology/Archaeology
Foreign Languages and Literatures (in French, German, Russian, or Spanish)
History
Literature
Music
Writing (Creative, Expository, Science Journalism, or Technical Communication)
Science, Technology, and Society (STS)

The required curriculum consists of eight to eleven subjects in the chosen discipline plus four subjects from a related field of humanities, arts, or social sciences. Depending on the field of specialization, the course of study may include special introductory or advanced seminars and a senior thesis. Faculty advisors in each of the disciplines help students to arrange programs suited to both their interests and professional objectives.

1
As a matter of general Course XXI policy, subjects used to meet the General Institute Science Requirement, the Science Distribution Requirement, and the Laboratory Requirement may not be included in the 6-subject Engineering or Science component of XXI-E or XXI-S. Only 1 subject being used to meet the Distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the Humanities component of these degree programs. For the class entering in September 1988 (Class of 1992), all but two HASS-Distribution subjects can be satisfied by subjects in the Departmental Program.

2
The cluster is usually formed within a single second discipline of the humanities, arts, or social sciences. In special cases it may draw together subjects from different disciplines to form a coherent grouping.

Bachelor of Science in Humanities Course XXI

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements[1]	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [all but two Humanities Distribution subjects can be satisfied by subjects in the Departmental Program]	8
Science Distribution Requirement	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Programs	**Units**
Restricted Electives:	
One of the following (further details may be obtained from the catalogue descriptions of programs in specific fields and the relevant field office)	
Anthropology/Archaeology 8 subjects in the field (including 21.503 or 21.504), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	127-162
Foreign Languages and Literatures (in French, German, Russian, or Spanish) 8 elective subjects in the field, a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	126-162
History 9 elective subjects in the field, a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	135-174
Literature 10 elective subjects in the field (including three seminars, and subjects in four historical periods) and a 4-subject cluster[2]	135-168
Music 11 subjects in the field including 4 in composition (21.641, 21.642, 21.643, and one more), 3 in history and literature of music (21.621, 21.622, and one more), 2 (6-unit subjects) in performance, 2 electives (excluding 21.60 and performance subjects), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	153-177
Writing Creative or Expository 9 subjects centered in creative or expository writing (one of these subjects will normally be at the introductory level and another at the advanced level; 2 may be chosen from a related field), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	135-174
Science Journalism or Technical Communication (The full major in Science Journalism or Technical Communication may be pursued only as a second degree program in conjunction with another degree program in a field of engineering or science.) 5 subjects in writing (including 21.782, 21.783, 21.792, and a subject in basic exposition), 4 subjects from related curricula (including, for Science Journalism, subjects in the history and social context of science/technology, or, for Technical Communication, 9.00, 4.871, and a subject in structure of business organizations), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	141-165
Restricted Electives (continued)	
Science, Technology, and Society (STS) (The full major in Science, Technology, and Society (STS) may be pursued only as a second degree program in conjunction with another degree program in a field of engineering or science.) 8 subjects in the field (including STS 091, STS 092, and STS 093, and study in three STS areas), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis	126-153
Units in Departmental Program that also satisfy the General Institute Requirements	54-72
Unrestricted Electives	57 to 108
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

Bachelor of Science in Humanities and Engineering Course XXI-E

Bachelor of Science in Humanities and Science Course XXI-S

These **joint** major programs combine humanities with scientific/engineering studies, creating an educational experience of unusual scope and balance. Groups of subjects from the humanistic and technical areas are conjoined to yield a substantial "dual literacy," a basic command of each mode of inquiry. One part is a selection from the undergraduate degree curriculum of a science or engineering department, or the Department of Brain and Cognitive Sciences, approved by a faculty member in the field. The other part consists of subjects in some field of the humanities, chosen by the student in consultation with an advisor from the appropriate humanistic faculty. In most cases a senior thesis or sequence of advanced seminars is also required.

This arrangement yields a humanities program of considerable depth while allowing for continued serious commitment to a scientific or engineering interest. Available humanities fields include:

Anthropology/Archaeology
Foreign Languages and Literatures (in French, German, Russian, or Spanish)
History
Literature
Music
Writing (Creative, Expository, Science Journalism, or Technical Communication)
American Studies
Latin American Studies
Russian Studies
Science, Technology, and Society (STS)

Any one of these fields may be joined with any Science or Engineering field to form a major. Some combinations naturally lend themselves not only to an understanding of each field but also to an integrative and comparative view of the relationship between the two.

In fact one field — Science, Technology, and Society (STS) — is designed expressly for this purpose. It includes a group of specially designated relational subjects offered by the faculties in Humanities and the Program in Science, Technology, and Society, which provide a focus for interdisciplinary work.

Bachelor of Science in Humanities and Engineering Course XXI-E

Bachelor of Science in Humanities and Science Course XXI-S

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements[1]	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [all but two Humanities Distribution subjects can be satisfied by subjects in the Departmental Program]	8
Science Distribution Requirement	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Restricted Electives:	
For the Humanities component, one of the following (further details may be obtained from the catalogue descriptions of programs in specific fields and the relevant field office)	
Anthropology/Archaeology 7 subjects (including 21.503 or 21.504), a pre-thesis tutorial, and a thesis	**84-99**
Foreign Languages and Literatures (in French, German, Russian, or Spanish) 7 elective subjects, a pre-thesis tutorial, and a thesis	**81-102**
History 7 elective subjects, a pre-thesis tutorial, and a thesis	**81-102**
Literature 8 elective subjects (including two seminars and subjects in three historical periods)	**78-96**
Music 8 subjects — including 21.621, 21.622, 21.641, 21.642, 2 (6-unit subjects) in performance, and 2 electives (excluding 21.60 and performance)	**81-108**
Writing Creative or Expository 7 subjects centered in creative or expository writing (one of these subjects will normally be at the introductory level and another at the advanced level; one may be chosen from a related field), a pre-thesis tutorial, and a thesis	**81-102**
Science Journalism or Technical Communication 4 subjects in writing (including 21.782, 21.783, 21.792, and a subject in basic exposition), 3 subjects from related curricula (including, for Science Journalism, subjects in the history and social context of science/technology, or, for Technical Communication, 9.00, 4.871, and a subject in the structure of business organizations), a pre-thesis tutorial, and a thesis	**87-93**
American Studies[2] 7 elective subjects (including two in history and two in literature), a pre-thesis tutorial, and a thesis	**81-102**
Latin American Studies[2] 7 elective subjects (including study in at least two disciplines and some work in Spanish), a pre-thesis tutorial, and a thesis	**81-102**
Russian Studies[2] 7 elective subjects (including two on society and two on culture), an approved creative project or a pre-thesis tutorial, and a thesis	**81-102**
Science, Technology, and Society (STS) 8 subjects (including STS 091 and STS 092 and study in two STS areas), a pre-thesis tutorial, and a thesis	**90-108**
And for the Engineering/Science component, one of the following:	
For XXI-E:	**54-72**
6 elective subjects restricted to one of the Engineering curricula and approved by a faculty member in the field[1,3]	
For XXI-S:	**54-72**
6 elective subjects restricted to one of the Science curricula and approved by a faculty member in the field[1,3]	
or	
6 subjects in Brain and Cognitive Sciences (detailed specifications available from the Department of Brain and Cognitive Sciences or Humanities Section/Program Offices)	
Units in Departmental Program that also satisfy the General Institute Requirements	**54-72**
Unrestricted Electives	**54 to 103**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

1
As a matter of general Course XXI policy, subjects used to meet the General Institute Science Requirement, the Science Distribution Requirement, and the Laboratory Requirement may not be included in the 6-subject Engineering or Science component of XXI-E or XXI-S. Only 1 subject being used to meet the Distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the Humanities component of these degree programs. For the class entering in September 1988 (Class of 1992), all but two HASS-Distribution subjects can be satisfied by subjects in the Departmental Program.

2
American Studies, Latin American Studies, and Russian Studies are also available as full majors by special arrangement with the Dean of the School of Humanities and Social Science.

3
When possible, the subject satisfying the Institute Laboratory Requirement and one of the subjects satisfying the Science Distribution Requirement should be selected from this same curriculum, in addition to the regular requirement.

Bachelor of Science in Humanities Course XXI

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements[1]	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program, plus two Humanities Distribution subjects totaling	18
Science Distribution Requirement	36
Laboratory Requirement	12

Departmental Programs

Restricted Electives:

One of the following (further details may be obtained from the catalogue descriptions of programs in specific fields and the relevant field office)

Anthropology/Archaeology
8 subjects in the field (including 21.503 or 21.504), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 129**

Foreign Languages and Literatures
(in French, German, Russian, or Spanish)
8 elective subjects in the field, a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 126**

Restricted Electives (continued)

History
9 elective subjects in the field, a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 135**

Literature
10 elective subjects in the field (including three seminars, and subjects in four historical periods) and a 4-subject cluster[2] — **at least 135**

Music
11 subjects in the field including 4 in composition (21.641, 21.642, 21.643, and one more), 3 in history and literature of music (21.621, 21.622, and one more), 2 (6-unit subjects) in performance, 2 electives (excluding 21.60 and performance subjects), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 153**

Writing
Creative or Expository
5 subjects centered in creative or expository writing (including one advanced subject), four subjects in a related field of humanities, arts, or social science, a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 135**

Science Journalism or Technical Communication
(The full major in Science Journalism or Technical Communication may be pursued only as a second degree program in conjunction with another degree program in a field of engineering or science.)

5 subjects in writing (including 21.782, 21.783, 21.792, and a subject in basic exposition), 4 subjects from related curricula (including, for Science Journalism, subjects in the history and social context of science/technology, or, for Technical Communication, 9.00, 4.871, and a subject in structure of business organizations), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 141**

Science, Technology, and Society (STS)
(The full major in Science, Technology, and Society (STS) may be pursued only as a second degree program in conjunction with another degree program in a field of engineering or science.)

8 subjects in the field (including STS 091, STS 092, and STS 093, and study in three STS areas), a 4-subject cluster[2], a pre-thesis tutorial, and a thesis — **at least 126**

Unrestricted Electives	**66 to 99**
Total Units Required for the S.B. Degree	**360**

1
As a matter of general Course XXI policy, subjects used to meet the General Institute Science Requirement, the Science Distribution Requirement, and the Laboratory Requirement may not be included in the 6-subject Engineering or Science component of XXI-E or XXI-S. Only 1 subject being used to meet the Distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the Humanities component of these degree programs.
2
The cluster is usually formed within a single second discipline of the humanities, arts, or social sciences. In special cases it may draw together subjects from different disciplines to form a coherent grouping.

Bachelor of Science in Humanities and Engineering Course XXI-E

Bachelor of Science in Humanities and Science Course XXI-S

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements[1]	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program, plus two Humanities Distribution subjects totaling	18
Science Distribution Requirement	36
Laboratory Requirement	12

Departmental Programs

Restricted Electives:

For the Humanities component, one of the following (further details may be obtained from the catalogue descriptions of programs in specific fields and the relevant field office)

Anthropology/Archaeology
7 subjects (including 21.503 or 21.504), a pre-thesis tutorial, and a thesis — **at least 84**

Foreign Languages and Literatures
(in French, German, Russian, or Spanish)
7 elective subjects, a pre-thesis tutorial, and a thesis — **at least 81**

1
As a matter of general Course XXI policy, subjects used to meet the General Institute Science Requirement, the Science Distribution Requirement, and the Laboratory Requirement may not be included in the 6-subject Engineering or Science component of XXI-E or XXI-S. Only 1 subject being used to meet the Distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the Humanities component of these degree programs.
2
American Studies, Latin American Studies, and Russian Studies are also available as full majors by special arrangement with the Dean of the School of Humanities and Social Sciences.
3
When possible, the subject satisfying the Institute Laboratory Requirement and one of the subjects satisfying the Science Distribution Requirement should be selected from this same curriculum, in addition to the regular requirement.

Restricted Electives (continued)	
History 7 elective subjects, a pre-thesis tutorial, and a thesis	**at least 81**
Literature 8 elective subjects (including two seminars and subjects in three historical periods)	**at least 78**
Music 8 subjects — including 21.621, 21.622, 21.641, 21.642, 2 (6-unit subjects) in performance, and 2 electives (excluding 21.60 and performance)	**at least 81**
Writing Creative or Expository 4 subjects centered in creative or expository writing (including one advanced subject), 3 subjects in a related field of humanities, arts, or social science, a pre-thesis tutorial, and a thesis	**at least 81**
Science Journalism or Technical Communication 4 subjects in writing (including 21.782, 21.783, 21.792, and a subject in basic exposition), 3 subjects from related curricula (including, for Science Journalism, subjects in the history and social context of science/technology, or, for Technical Communication, 9.00, 4.871, and a subject in the structure of business organizations), a pre-thesis tutorial, and a thesis	**at least 87**
American Studies[2] 7 elective subjects (including two in history and two in literature), a pre-thesis tutorial, and a thesis	**at least 81**
Latin American Studies[2] 7 elective subjects (including study in at least two disciplines and some work in Spanish), a pre-thesis tutorial, and a thesis	**at least 81**
Russian Studies[2] 7 elective subjects (including two on society and two on culture), an approved creative project or a pre-thesis tutorial, and a thesis	**at least 81**
Science, Technology, and Society (STS) 8 subjects (including STS 091 and STS 092 and study in two STS areas), a pre-thesis tutorial, and a thesis	**at least 90**
And for the Engineering/Science component, one of the following:	
For XXI-E:	**at least 54**
6 elective subjects restricted to one of the Engineering curricula and approved by a faculty member in the field[1,3]	
For XXI-S:	**at least 54**
6 elective subjects restricted to one of the Science curricula and approved by a faculty member in the field[1,3] *or* 6 subjects in Brain and Cognitive Sciences (detailed specifications available from the Department of Brain and Cognitive Sciences or Humanities Section/Program Offices)	
Unrestricted Electives	**85 to 96**
Total Units Required for the S.B. Degree	**360**

Department of Linguistics and Philosophy

(Course 24)

Undergraduate Study

Richard Lee Cartwright, Ph.D.
Professor of Philosophy
Head of the Department

Professors

Ned Block, Ph.D.
Professor of Philosophy
(On leave)

George Stephen Boolos, Ph.D.
Professor of Philosophy

Sylvain Bromberger, Ph.D.
Professor of Philosophy

Noam Avram Chomsky, Ph.D.
Institute Professor
Professor of Linguistics

Kenneth Locke Hale, Ph.D.
Ferrari P. Ward Professor of
Modern Languages and Linguistics

Morris Halle, Ph.D.
Institute Professor
Professor of Linguistics

James Wesley Harris, Ph.D.
Professor of Spanish and
Linguistics
(On leave, fall)

James Higginbotham, Ph.D.
Professor of Philosophy

Paul Horwich, Ph.D.
Professor of Philosophy
(On leave, fall)

Samuel Jay Keyser, Ph.D.
Professor of Linguistics
Director, Center for Cognitive Science
Associate Provost for Educational
Programs and Policy

Thomas Samuel Kuhn, Ph.D.
Laurance S. Rockefeller
Professor of Philosophy and
History of Science

Wayne O'Neil, Ph.D.
Professor of Linguistics
(On leave, spring)

Daniel Nathan Osherson, Ph.D.
Professor of Psychology

Irving Singer, Ph.D.
Professor of Philosophy

Robert Stalnaker, Ph.D.
Professor of Philosophy

Judith Jarvis Thomson, Ph.D.
Professor of Philosophy

Associate Professors

Joshua Cohen, Ph.D.
Associate Professor of Philosophy
and Political Science
(On leave, spring)

Richard K. Larson, Ph.D.
Associate Professor of Linguistics

Donca Steriade, Ph.D.
Associate Professor of Linguistics
(On leave)

Assistant Professors

David Owen Brink, Ph.D.
Assistant Professor of Philosophy

Michael Oliver Hardimon, Ph.D.
Assistant Professor of Philosophy

Paul Hoffman, Ph.D.
Assistant Professor of Philosophy

Visiting Professors

Michael Kenstowicz, Ph.D.
Professor of Linguistics

Georges Rey, Ph.D.
Associate Professor of Philosophy

Administrative Officer

Marilyn Matthes Silva, A.B.

As its name suggests, the Department of Linguistics and Philosophy houses a linguistics section and a philosophy section. Though they share a number of intellectual interests, these two sections are administratively autonomous in that they have separate chairpersons, faculties, admissions procedures, curricular and degree requirements, and financial aid programs.

The linguistics section offers a program leading to the Doctor of Philosophy in Linguistics. The Master of Science degree is awarded only in exceptional circumstances. There is no undergraduate degree program in linguistics, though the section does offer undergraduate subjects that may be taken as electives by any student or as part of the Course IX Cognitive Science and the Course XXIV Language and Mind programs.

Philosophy aims at analysis and criticism of the concepts and principles fundamental to the sciences, to our commonsense view of the world, and to our modes of valuation. The study of philosophy is thus appropriate for those who enjoy thinking carefully and logically about basic issues, for those who seek perspective on a scientific education, and for those who wish breadth of educational experience prior to entering professional programs such as law or medicine.

The goal of the **Minor Program** is to introduce students to the methods of analytic philosophy and then to have them study a broad range of philosophers and philosophical issues at a more sophisticated level, culminating in an advanced seminar.

The Minor Program in Philosophy consists of six subjects arranged into three levels of study as follows:

TIER I: Two subjects, including:

Any introductory philosophy subject (subject without prerequisite)
and
24.241 Logic I

TIER II: Three intermediate subjects in Philosophy chosen as follows:

One from among
24.200 Ancient Philosophy
24.202 Modern Philosophy: Descartes to Kant
24.203 Aspects of Twentieth-Century Philosophy
24.204 Existentialism
and one from among
24.211 Theory of Knowledge
24.221 Metaphysics
24.231 Ethics
and one from among
24.151 Introduction to Philosophy of Language
24.210 Problems in the Philososphy of Love
24.211 Theory of Knowledge
24.221 Metaphysics
24.231 Ethics
24.233J Political Philosophy
24.235J Philosophy of Law

TIER III: One subject:
24.260 Topics in Philosophy

The introduction to the School of Humanities and Social Science found earlier in this chapter describes the Department in the larger context of the School and of the Institute.

Bachelor of Science in Philosophy Course XXIV

The philosophy section offers two undergraduate programs leading to the degree of Bachelor of Science in Philosophy, as well as a program leading to the doctorate in philosophy. These programs are described in detail in the following paragraphs.

Two programs are offered leading to the degree of Bachelor of Science in Philosophy. Program 1 is designed to provide 1) familiarity with the history and current status of the main problems in epistemology, metaphysics, and ethics; 2) mastery of some of the technical skills requisite for advanced work in philosophy; 3) facility at independent philosophical study; and 4) work at an advanced level in an allied field. A relatively large amount of unrestricted elective time is available so that students can devise programs suited to individual needs and interests.

Program 2, called the program in Language and Mind, addresses itself to topics and problems related to philosophy, psychology, linguistics, and artificial intelligence that do not fall neatly into any one of those fields. Central among these topics are the nature of language, of mental representation of knowledge, and of the innate basis for the acquisition of such knowledge. A core set of seven subjects is required for the purpose of teaching students the central facts and issues in the study of language and the representation of knowledge. A further requirement of specialization within the program of four additional subjects in one of the fields is designed to ensure preparation for graduate study in either philosophy or psychology or linguistics. Lists of subjects in philosophy, linguistics, psychology, and artificial intelligence, which may be used to satisfy the restricted elective requirement, may be obtained from the Department.

Bachelor of Science in Philosophy Course XXIV Program 1

Degree requirements applicable to the Class entering MIT in September 1986[1] (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [3 subjects can be satisfied by subjects in the Departmental Program (for the Field of Concentration)]	8
Science Distribution Requirement	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Subject names below are followed by credit units; all except 24.241 and 24.260 have as a prerequisite one previous philosophy subject	
Required Subjects:	**72**
24.200 Ancient Philosophy, 12	
24.202 Modern Philosophy: Descartes to Kant, 12	
24.260 Topics in Philosophy[1,2], 12	
One of the following two subjects:	
24.211 Theory of Knowledge, 12	
24.221 Metaphysics, 12	
plus	
24.231 Ethics, 12	
24.241 Logic I, 12	
Restricted Electives[1]:	**45-60**
A coherent program of 5 subjects, of which 2 must be in philosophy and 3 in advanced subjects in some other discipline	
Units in Departmental Program that also satisfy the General Institute Requirements	**(27-36)**
Unrestricted Electives	**75-102**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

1
Students entering MIT in September 1986 and 1987 (Classes of 1990 and 1991) may take an additional restricted elective in place of 24.260; this restricted elective must be in an advanced subject in a discipline other than philosophy.
2
Prereq.: Two subjects in philosophy.

Bachelor of Science in Philosophy
Course XXIV
Program 2: Language and Mind

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [all but two Humanities Distribution subjects can be satisfied by subjects in the Departmental Program]	8
Science Distribution Requirement	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program — **Units**

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 75-78

24.119 Minds and Machines, 12
24.151 Introduction to Philosophy of Language, 9
24.241 Logic I, 12
24.900J The Study of Language, 12
24.901J Language and Its Structure, 12; 24.900J

Two of the following three subjects:
9.59 Psychology of Language and Communication, 9; 24.900J or 24.116J
9.65 Cognitive Processes, 9
24.116J Introduction to Cognitive Science, 12

Restricted Electives: 45-60

A coherent program of 5 additional subjects which normally should be chosen from one or two of the four areas: Philosophy, Linguistics, Psychology, Artificial Intelligence (see text)

Units in Departmental Program that also satisfy the General Institute Requirements (54-60)

Unrestricted Electives 114-123

Total Units Required for the S.B. Degree Beyond the General Institute Requirements 180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

Bachelor of Science in Philosophy
Course XXIV
Program 1

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program (for the Field of Concentration), plus appropriate subjects totaling	45
Science Distribution Requirement	36
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units; all except 24.241 have as a prerequisite one previous philosophy subject

Required Subjects: 60

24.200 Ancient Philosophy, 12
24.202 Modern Philosophy: Descartes to Kant, 12

One of the following two subjects:
24.211 Theory of Knowledge, 12
24.221 Metaphysics, 12

plus

24.231 Ethics, 12
24.241 Logic I, 12

Restricted Electives: 54-72

A coherent program of 6 subjects, of which 2 must be in philosophy and 4 in advanced subjects in some other discipline

Unrestricted Electives 75-93

Total Units Required for the S.B. Degree 360

Bachelor of Science in Philosophy
Course XXIV
Program 2: Language and Mind

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program, plus two Humanities Distribution subjects totaling	18
Science Distribution Requirement	36
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 75-78

24.119 Minds and Machines, 12
24.151 Introduction to Philosophy of Language, 9
24.241 Logic I, 12
24.900J The Study of Language, 12
24.901J Language and Its Structure, 12; 24.900J

Two of the following three subjects:
9.59 Psychology of Language and Communication, 9; 24.900J or 24.116J
9.65 Cognitive Processes, 9
24.116J Introduction to Cognitive Science, 12

Restricted Electives: 45-60

A coherent program of 5 additional subjects which normally should be chosen from one or two of the four areas: Philosophy, Linguistics, Psychology, Artificial Intelligence (see text)

Unrestricted Electives 96-114

Total Units Required for the S.B. Degree 360

Graduate Study

The Department offers two programs leading to the degree of Doctor of Philosophy, one in linguistics and one in philosophy.

Doctor of Philosophy in Linguistics

The linguistics section offers a demanding program leading to the degree of Doctor of Philosophy in Linguistics. The normal course of study is four years, including the writing of the dissertation. The orientation of the program is highly theoretical, its central aim being the development of a general theory that reveals the rules and laws that govern the structure of a given language and the general laws and principles that govern all natural languages. The topics that form the core of this program are the traditional ones of phonology, morphology, syntax, semantics, and historical linguistics; but the program's interests also extend into questions of the interrelations between linguistics and other disciplines such as philosophy and logic, literary studies, mathematics and the study of formal languages, acoustics, artificial intelligence, and computer science.

Approximately eight to 10 students enter the program each year in a highly selective admissions process. The Department does not require that applicants have taken any particular set of subjects or that they be trained in any particular discipline. Instead, applicants must present evidence that they are able to engage in serious study of complex subject matter. Examples of such evidence might be mastery in depth of a language or group of languages, e.g., classical Greek, Semitic, Japanese; or work, academic or nonacademic, of high quality in a relevant area, especially if it required considerable application, imagination, or ingenuity.

All students in the linguistics program must complete a set of required subjects unless they have acquired adequate preparation elsewhere. A program of studies in a minor field is also required in order to broaden the student's educational experience. Before degree candidates begin their doctoral research they are required to pass a comprehensive General Examination, in conformity with Institute requirements. Students must also demonstrate competence in two foreign languages.

The following subjects are normally required of all doctoral candidates in linguistics, unless they have obtained adequate preparation elsewhere:

24.942	Topics in the Grammar of a Non-Indo-European Language
24.951	Introduction to Linguistics I: Syntax
24.961	Introduction to Linguistics II: Phonology
24.952	Introduction to Linguistics III: Theory of Grammar
24.957	Introduction to Linguistic Theory at an Advanced Level
24.958	Linguistic Structure
24.959	Workshop in Syntax and Semantics
24.962	Advanced Phonology
24.969	Workshop in Phonology and Morphology
24.970	Introduction to Semantics
24.973	Topics in Logic and Semantics
24.992	Survey of General Linguistics I
One of the following:	
24.956	Introduction to Linguistics IV: Universal Grammar
24.964	Theory of Phonology
24.979	Semantic Theory

Before students may begin their doctoral research, they are required to pass a comprehensive General Examination that is composed of two parts. The first part is a written examination consisting of two substantial papers on topics chosen in consultation with members of the faculty. Usually one paper is on phonology or morphology and the other on syntax or semantics, but it is possible for one or both papers to treat the interaction of two topics, for example the interaction between syntax and semantics. In conformity with Institute regulations, the second part of the examination is oral. It deals with topics treated in the candidate's written examination, but is not limited to these and probes into the candidate's competence in linguistics in general.

Every candidate for the doctorate must complete a program of studies in a minor field, the purpose of which is to broaden the interests and capacities of the student in areas other than those of his or her major intellectual objective.

Doctor of Philosophy in Philosophy

The program of studies leading to the doctorate in philosophy provides courses and seminars in such traditional areas as logic, ethics, metaphysics, epistemology, philosophy of science, philosophy of language, philosophy of mind, aesthetics, social and political philosophy, and history of philosophy. Interest in philosophical problems arising from other disciplines, such as linguistics, psychology, mathematics, and physics, is also encouraged.

To enter the doctoral program, students must have done well in their previous academic work and must be formally accepted as candidates for the degree by the Department of Linguistics and Philosophy. Although there are no formal course requirements for admission, applicants must satisfy the committee on admissions that their preparation in philosophy and allied disciplines is sufficient for undertaking study of philosophy at the graduate level.

Before beginning dissertation research, students are required to take two years of course work including a proseminar in contemporary philosophy that all students must complete in their first year of graduate study. Students are also required to pass general examinations and demonstrate competence in the following areas; value theory, logic, and the history of philosophy.

Interdisciplinary study is encouraged, and candidates for the doctorate may take a minor in a field other than philosophy. Options for minors include psychology, linguistics, and logic. Students who elect one of these options will be expected to complete three approved graduate subjects in their minor field. There is no general language requirement for the doctorate, except in those cases in which competence in one or more foreign languages is needed to carry on research for the dissertation.

Inquiries

Information regarding undergraduate or graduate academic programs, research activities, admissions, financial aid, and assistantships may be obtained from the Department of Linguistics and Philosophy, Room 20D-213, MIT, Cambridge, Massachusetts 02139, (617) 253-4141.

Department of Political Science

Donald Laurence Morton Blackmer, Ph.D.
Professor of Political Science
Head of the Department
(Fall term)

Suzanne Berger, Ph.D.
Ford International Professor of Political Science
Head of the Department
(Spring term)

Richard Joel Samuels, Ph.D.
Associate Professor of Political Science
Associate Head of the Department
(Spring term)

Professors

Hayward Rose Alker, Jr., Ph.D.
Professor of Political Science
(On leave, spring)

Lincoln Palmer Bloomfield, Ph.D.
Professor of Political Science

Walter Dean Burnham, Ph.D., Lit.D.
Ruth and Artnur Sloan Professor of Political Science
(On leave)

Nazli Choucri Field, Ph.D.
Professor of Political Science

William Edgar Griffith, Ph.D.
Ford International Professor of Political Science

Willard Raymond Johnson, Ph.D.
Professor of Political Science

Michael Lipsky, Ph.D.
Professor of Political Science

Lucian Wilmot Pye, Ph.D., L.L.D.
Ford International Professor of Political Science
(On leave, spring)

George William Rathjens, Ph.D.
Professor of Political Science

Charles Frederic Sabel, Ph.D.
Professor of Social Science
(On leave, fall)

Harvey Morton Sapolsky, Ph.D.
Professor of Public Policy and Organization

Eugene Bertram Skolnikoff, Ph.D.
Professor of Political Science
(On leave, spring)

Myron Weiner, Ph.D.
Ford Professor of Political Science
Director, Center for International Studies

Associate Professors

Joshua Cohen, Ph.D.
Associate Professor of Political Science and Philosophy

Stephen Michael Meyer, Ph.D.
Associate Professor of Political Science

Barry R. Posen, Ph.D.
Associate Professor of Political Science

Assistant Professors

Jonathan A. Fox, Ph.D.
Assistant Professor of Political Science

Ellen Immergut, Ph.D.
Assistant Professor of Political Science

Richard M. Locke, M.A.
Assistant Professor of Management and Political Science

Uday Mehta, Ph.D.
Assistant Professor of Political Science

Steven E. Miller, Ph.D.
Asssitant Professor of Political Science

Charles Stewart III, Ph.D.
Assistant Professor of Political Science

Richard M. Valelly, Ph.D.
Assistant Professor of Political Science

Lecturers

Peter H. Lemieux, Ph.D.
Louis Menand III, Ph.D.
(Visiting, spring)
William Russell Neuman, Ph.D.

Administrative Officer

Anne M. Grazewski, B.A.

Administrative Staff

Maryann S. Lord
Frances F. Powell

Professors Emeriti

Everett Hagen, Ph.D.
Professor of Economics and Political Science, Emeritus

William Weed Kaufmann, Ph.D.
Professor of Political Science, Emeritus

Department of Political Science

(Course 17)

Undergraduate Study

Political science is concerned with the systematic study of government and the political process. Within the discipline, scholars analyze the development, distribution, and uses of political power; the determinants and consequences of various forms of political behavior and sources of political conflict; the ways in which conflicts are both intensified and resolved; and the relationship between the individual and the state. It is a discipline of special interest to scientists and engineers who must understand the political system within which they live in order to evaluate their influence upon that system. It is of interest as well to those students who are considering careers in public service or university teaching and research.

The Department has a research-oriented faculty that welcomes the association of both undergraduate and graduate students in ongoing research. Among the major features of the Department are 1) an emphasis on empirical methods and research training; 2) a concern with issues of public policy, particularly in the areas of arms control and defense, science policy, urban affairs, health, communications, population and migration, and foreign policy; 3) comparative studies involving the United States and other advanced industrial societies, the developing countries of the third world, and communist countries; and 4) a strong interdisciplinary perspective that incorporates political sociology, political psychology, political demography, and economic and political development.

The **Minor Program** is designed to ensure that students acquire both depth and breadth of understanding in the discipline. A minor in Political Science consists of six subjects. The requirements for the Minor parallel the requirements for the Major and are structured as follows:

TIER I: Two or three introductory Political Science subjects from *different* subfields of the curriculum:

1) Political Philosophy
2) American Politics
3) Non-American or International Politics
4) Public Policy

TIER II: Two or three upper level undergraduate subjects in *one* of the following areas of specialization:

1) Political Philosophy
2) American Politics
3) Non-American or International Politics
4) Public Policy

TIER III: At least one subject from the following:

17.203	Political Science Laboratory
17.907	Reading Seminar in Social Science
17.912	Junior Colloquium in Political Science and Public Affairs

IN ADDITION: A Minor in Political Science must include at least two substantial research papers of the sort normally required in Tier II subjects. A senior research paper can fulfill this requirement.

For a listing of available subjects in these areas, consult the Political Science Undergraduate Office (E53-600) or the HASS Information Office (14N-408).

The Department offers degree programs at the bachelor's, master's, and doctoral levels. The introduction to the School of Humanities and Social Science found earlier in this chapter describes the Department in the larger context of the School and of MIT.

Bachelor of Science in Political Science Course XVII

The political science curriculum for undergraduates combines professional social science training with opportunities for a broad liberal arts education. Students are able to choose subjects from a wide range of both undergraduate and graduate offerings, and they are also encouraged to engage in independent research projects. In addition, the Department sponsors a variety of fieldwork programs in governmental agencies at all levels.

The undergraduate program prepares students for study in political science, law, public policy, and related fields, and for careers in government, business, law, research, teaching, or journalism. This program is also designed to give students, whatever their career objectives, an understanding of political institutions and processes. Some students want to focus on political systems themselves; others choose to concentrate on the political aspects of public policy, focusing on such issues as transportation, health, or arms control. Both of these perspectives are found in the program.

Subjects are offered by the Department in the following fields: political theory, American politics and public policy, urban politics and policy, science and public policy, defense and arms control policy, political psychology, political development, political communications and behavior, comparative politics, and international relations and foreign policy. Students' individualized programs are worked out with the assistance of a faculty advisor.

The Department believes that every political science major should have the experience of conducting and writing at least one substantial research project, a requirement that is fulfilled by the senior thesis. Each undergraduate chooses a thesis advisor in his or her area of interest. The student then registers for Prethesis Reading Seminar in the fall term and for Thesis in the spring term of the senior year.

In addition to the thesis, there are numerous other opportunities for students to pursue research interests. For example, a student may wish to take an independent reading subject in an area for which no formal subject is being offered. Also, students are eligible to receive academic credit or limited funding for expenses or wages through the Institute-wide Undergraduate Research Opportunities Program. Students should consult the Department's UROP coordinator to discuss specific projects.

Graduate Study

Bachelor of Science in Political Science Course XVII

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:

General Institute Requirements		17 Subjects
Science Requirement		5
Humanities, Arts, and Social Sciences Requirement [3 subjects can be satisfied by subjects in the Departmental Program]		8
Science Distribution Requirement[1]		3
Laboratory Requirement		1
	TOTAL Subjects	17

PLUS

Departmental Program		Units
Required Subjects:		24
17.913	Pre-thesis Reading Seminar (9 units)	
17.ThU	Undergraduate Political Science Thesis (at least 15 units; additional units by special arrangement)	
Restricted Electives:		81-108

Normally 9 subjects divided as follows:

a. At least one subject that provides exposure in depth to each of the following four aspects of political science:

- Political Philosophy
- American Polity
- A Non-American or International Perspective
- Public Policy

b. Five additional political science subjects

Specific subjects satisfying these criteria should be chosen in consultation with a faculty advisor.

Units in Departmental Program that also satisfy the General Institute Requirements	(27-36)
Unrestricted Electives	90-108
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

[1] 1.00 Introduction to Computers and Engineering Problem Solving and 14.30 Introduction to Statistical Method in Economics are suggested.

Bachelor of Science in Political Science Course XVII

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement		60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program, plus appropriate subjects totaling		45
Science Distribution Requirement[1]		36
Laboratory Requirement		12
Departmental Program		
Required Subjects:		18
17.913	Pre-thesis Reading Seminar (9 units)	
17.ThU	Undergraduate Political Science Thesis (at least 9 units)	
Restricted Electives:		at least 81

Normally 9 subjects divided as follows:

a. At least one subject that provides exposure in depth to each of the following four aspects of political science:

- Political Philosophy
- American Polity
- A Non-American or International Perspective
- Public Policy

b. Five additional political science subjects

Specific subjects satisfying these criteria should be chosen in consultation with a faculty advisor.

Unrestricted Electives	108
Total Units Required for the S.B. Degree	360

[1] 1.00 Introduction to Computers and Engineering Problem Solving and 14.30 Introduction to Statistical Method in Economics are suggested.

The Department of Political Science offers work leading to the Master of Science in Political Science and the Doctor of Philosophy.

Entrance Requirements for Graduate Study

There are no absolute prerequisites for admission to the graduate program, but students are expected to have taken at least six term subjects in English, history, and other fields of the humanities and social sciences. It is recommended that candidates for the doctoral program take at least one upper-level subject on the history of political thought and one term of statistics. Candidates for master's and doctoral programs are advised to take undergraduate subjects in areas relevant to their special fields of interest, for example, introductory economics for work in public policy; languages for area studies; science or engineering subjects for study in science, technology, and public policy; and mathematics for work in defense and arms control.

Master of Science in Political Science

The Master of Science is intended for students who are concerned with developing skills in applied research and who are seeking careers in public service. The master's program emphasizes intensive preparation in a single field of study. Applications should describe the field in which students wish to specialize.

Subjects need not be restricted to those offered within the Department, but the entire program must meet with the approval of the student's advisor. A thesis is required. See Chapter IV for the general requirements for the S.M.

Accelerated Master of Science in Political Science

The Department offers a five-year program leading to the Bachelor of Science and Master of Science, awarded simultaneously. This program is open to MIT undergraduates only. It allows the student to plan for a single combined S.B.-S.M. thesis written during the last three terms at the Institute. Undergraduate Institute requirements may be completed during the fifth year of the program.

Doctor of Philosophy

Candidates for the doctorate must prepare themselves in four approved fields of study. Two of these fields (the required field of political analysis and one other) are normally satisfied by completing stipulated subjects or

demonstrating achieved competence. The remaining two fields are the focus of the student's General Examination, written and oral. The student is also required to present and defend an advanced research paper (Second Year Paper) prior to the General Examination. Established fields include political analysis, political communication and behavior, American government, comparative politics, communist studies, defense policy, science technology and public policy, international politics and foreign policy, political and economic development, concepts and methods, urban politics, West European politics, Latin American politics, political demography, and others.

Approved combinations of some of these fields — together with economics, industrial management, sociology, social psychology, or science and engineering fields — are acceptable. Students are encouraged to take subjects in other MIT departments. Cross-registration arrangements also permit enrollment in subjects taught in the Graduate School of Arts and Sciences at Harvard University and in some of Harvard's other graduate schools.

Programs of study logically combining advanced work in some scientific, engineering, management, or other social science field with political science are welcomed. For example, some political science students have developed programs around the interdisciplinary field of communications policy. Graduate work in this field at MIT is described in more detail in Chapter VI. A candidate's qualifications for interdisciplinary programs must indicate promise of ability to develop fruitful new lines of inquiry on problems touching the relationship of government, human behavior, science, technology, and the political process.

Guided field research and close working ties with faculty members engaged in major research activities are stressed.

Teaching and Research Assistantships

Financial assistance is available to qualified applicants in the form of research assistantships, graduate traineeships, and a limited number of fellowships, subject to the availability of funds. Research assistants work under faculty supervision on projects administered by the Department and through MIT affiliated research facilities such as the Center for International Studies and the Center for Technology, Policy, and Industrial Development (both described in Chapter VI). In addition, advanced graduate students may qualify to become teaching assistants.

Inquiries

Additional information regarding academic and research programs in the Department, admissions, assistantships, financial aid, etc., may be obtained from the Administrator, Graduate Student Affairs, Ms. Maryann Lord, E53-470, MIT, Cambridge, Massachusetts 02139, (617) 253-5262.

Program in Science, Technology, and Society

(STS)

Kenneth Keniston, Ph.D.
Andrew W. Mellon Professor of Human Development
Director

Professors

Loren R. Graham, Ph.D.
Professor of the History of Science
(On leave, fall)

Carl Kaysen, Ph.D.
David W. Skinner Professor of Political Economy
(On leave, spring)

Thomas Samuel Kuhn, Ph.D.
Laurance S. Rockefeller Professor of Philosophy and History of Science

Kenneth Rogers Manning, Ph.D.
Professor of the History of Science
Head, Writing Program

Leo Marx, Ph.D.
William R. Kenan Professor of American Cultural History

Michael Joseph Piore, Ph.D.
Mitsui Professor in Problems of Contemporary Technology
Professor of Economics

Charles Frederic Sabel, Ph.D.
Associate Professor of Social Science
(On leave, fall)

Merritt Roe Smith, Ph.D.
Professor of the History of Technology
(On leave, spring)

Leon Trilling, Ph.D.
Professor of Aeronautics and Astronautics

Charles Weiner, Ph.D.
Professor of the History of Science and Technology
(On leave, fall)

Associate Professors

Louis Lawrence Bucciarelli, Ph.D.
Associate Professor of Engineering and Technology Studies
(On leave)

Richard A. Lester, Ph.D.
Associate Professor of Nuclear Engineering

Sherry Roxanne Turkle, Ph.D.
Associate Professor of Sociology
(On leave)

Assistant Professors

Deborah Fitzgerald, Ph.D.
Assistant Professor of the History of Technology

Lisa Rofel, Ph.D.
Assistant Professor of Anthropology and Science, Technology, and Society

Visiting Professors

Jill Conway, Ph.D.

Gerald Holton, Ph.D.
Professor of the History of Science

Senior Research Associate

Victor McElheny, B.A.

Principal Research Scientist

Kosta Tsipis, Ph.D.

Professors Emeriti

Elting Elmore Morison, A.M.
Elizabeth and James Killian Class of 1926 Professor, Emeritus

Walter Alter Rosenblith, Ing. Rad.
Institute Professor, Emeritus
Provost, Emeritus

Jerome Bert Wiesner, Ph.D.
Institute Professor, Emeritus
President, Emeritus

The Program in Science, Technology, and Society (STS) focuses on the ways in which scientific, technological, and social factors interact to shape modern life. The Program brings together humanists, social scientists, engineers, and natural scientists, all committed to transcending the boundaries of their disciplines in a joint search for new insights and new ways of reaching science and engineering students. The goal of the Program is to set up a forum to explore the relationship between what scientists and engineers do and the constraints, needs, and responses of society. The introduction to the School of Humanities and Social Science found earlier in this chapter describes the Program in the larger context of the School and of MIT.

Undergraduate Study

Engineering and science students are increasingly seeking to understand the social and historical contexts in which they will work and the social consequences of what they will do in their professional careers. STS subjects help them think realistically and creatively about the intellectual, moral, and social issues raised by the rapid growth of science and technology in the 20th century.

STS contributes to undergraduate education at MIT in several ways. It offers general subjects to introduce science and engineering students to broad social and intellectual perspectives on their fields. It also offers more specialized subjects in three areas: the social and historical study of science and technology; technology and the organization of industrial societies; and cultural dimensions of science and technology. Within each of these categories, students can choose both introductory and more advanced subjects.

All STS undergraduate subjects may count toward the Institute Requirement in the Humanities, Arts, and Social Sciences. The Program offers a number of Humanities Distribution subjects as well as a Field of Concentration.

The goal of the **Minor Program** is to give students majoring in engineering or one of the sciences a broader perspective on their fields, how they have evolved, and how they fit into the wider context of society, culture, politics, and values.

The Minor Program in Science, Technology, and Society consists of six subjects as follows:

TIER I: One HASS-D, Context, or HUM-D subject from one of the two areas in the Science, Technology, and Society curriculum:

1) History of Science and Technology
2) Social Study of Science and Technology

TIER II: Three Advanced Undergraduate Subjects in one of these areas:

1) History of Science and Technology
2) Social Study of Science and Technology

and

One advanced undergraduate subject from the area *not* chosen, *or* from the History Faculty curriculum, *or* from the Anthropology/Archaeology Faculty curriculum

TIER III: One STS reading seminar

IN ADDITION: Students will participate in a monthly dinner meeting where they will have the opportunity to speak about their research and studies with other STS students and faculty.

A student may elect to do 9-12 units of UROP for credit, or do a joint thesis with his/her home department.

Double Degree Program

For those students who wish to integrate their professional study of engineering or science with a rigorous treatment of its relation to social and historical forces, STS offers a double degree program through Course XXI in cooperation with the Department of Humanities and several departments in the Schools of Engineering and Science. The object of this degree program is to give such students the full technical and scientific education provided by a science or engineering major, and to enrich it with complementary studies of the historical and social contexts in which science and technology function.

Students in this double degree program must complete all the requirements of their technical majors as well as the Course XXI requirements described as follows. Altogether they must complete 450 units of study to receive the two S.B. degrees.

The Course XXI degree requirements in STS are specified in the following chart. The two Reading Seminars (STS 091 and STS 092) are designed to provide a basic grounding in the study of science, technology, and society.

A coherent sequence of five elective subjects must be arranged to provide an understanding in depth of one of the following fields that comprise STS and some familiarity with the other two:

a) Social and Historical Studies of Science and Technology
b) Technology and the Organization of Industrial Societies
c) Cultural Dimensions of Science and Technology

In the Project Seminar (STS 093), to be taken in the third or fourth year, students reexamine from an STS perspective a laboratory project or summer job experience in the sciences or engineering. The Project Seminar provides training for work in STS in much the same way as laboratory subjects do for engineering or science.

In the Thesis or Design Project (21.ThU), students expand their senior technical thesis or design project to include the social effects and historical contexts of their work. In cases where an integrated study is not feasible, two separate but related projects may be considered.

Students must submit to the Registrar a petition that indicates the desire to work for this double degree. The petition must be approved by faculty advisors in the two appropriate departments before students complete the entire program. Students who take a normal load of subjects may require five years to complete this program, but the majority of double degree candidates finish their work in four years.

Double Degree Program Course XXI (STS/Humanities) with a Science or Engineering Course

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [all but two Humanities Distribution subjects can be satisfied by subjects in the departmental program]	8
Science Distribution Requirement	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program (STS/Humanities)	Units
Required Subjects:	45
Thesis (21.ThU) — 18 units	
Reading Seminar in Humanities, Science, and Technology I and II (STS 091 and STS 092) — 18 units	
Project Seminar (STS 093) — 9 units	
Planned Electives:	90-108
A coherent group of five elective subjects (at least 45 units) drawn from the curricula of STS, the Department of Humanities, and other departments where appropriate. Three of these subjects must be in one of the following areas, and two from the other:	
a) History of Science and Technology b) Social Study of Science and Technology	
Four elective subjects (at least 36 units) in a second discipline of humanities, social sciences, or visual arts	
Units in Departmental Program that also satisfy the General Institute Requirements	(54-72)
Unrestricted Electives	84-102
Total Units Required for the S.B. Degree in Course XXI (STS/Humanities) Beyond the General Institute Requirements	180
Total Units Required for Two Bachelor's Degrees Beyond the General Institute Requirements	270

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

Joint Degree Program

Students who wish to integrate studies in STS, Humanities, and Science/Engineering on the smaller scale of a single degree program should consider this option. The program includes a group of specially designated subjects offered by STS and the Department of Humanities that provide a focus for interdisciplinary work. Central to this core is a year-long reading seminar (STS 091 and STS 092), taught by faculty members from STS and Humanities, which examines interaction of science, technology, and culture through critical discussion of major works.

The six elective subjects in STS/Humanities required for the degree may be taken from the curricula of Humanities, STS, and other departments when appropriate. They must form a coherent grouping that includes at least one basic subject in the history of science or technology and one subject treating the cultural dimensions of science and technology, and that has clear relevance to the scientific/technical field forming the other component of the program.

Further details on the requirements for this joint degree program may be found under the Department of Humanities.

Double Degree Program Course XXI (STS/Humanities) with a Science or Engineering Course

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program, plus three Humanities Distribution subjects totaling	27
Science Distribution Requirement	36
Laboratory Requirement	12

Departmental Program (STS/Humanities)	
Required Subjects:	45
Thesis (21.ThT) — 6 units	
Thesis (21.Th) — 12 units	
Reading Seminar in Humanities, Science, and Technology I and II (STS 091 and STS 092) — 18 units	
Project Seminar (STS 093) — 9 units	
Planned Electives:	at least 90
A coherent group of five elective subjects (at least 45 units) drawn from the curricula of STS, the Department of Humanities, and other departments where appropriate. Three of these subjects must be in one of the following areas, and two from the other:	
a) History of Science and Technology b) Social Study of Science and Technology	
Four elective subjects (at least 36 units) in a second discipline of humanities, social sciences, or visual arts	
Unrestricted Electives	103
Total Units Required for the S.B.Degree in Course XXI (STS/Humanities)	360
Total Units Required for Two Bachelor's Degrees	450

STS offers several graduate-level subjects in addition to reading and research seminars. Graduate students are encouraged to participate in faculty research projects. With departmental permission, they can structure special concentrations or minor fields in STS as part of their degree programs. Such arrangements have been made with students in the Departments of Political Science and Economics interested in the history of science and technology, science and public policy, or the comparative study of advanced industrial societies. STS has provided financial assistance for some of these students. We expect these interdepartmental arrangements to expand. Interested students may also take advantage of the opportunity MIT offers to arrange doctoral programs supervised by an ad hoc committee of faculty members from STS and one or more other departments.

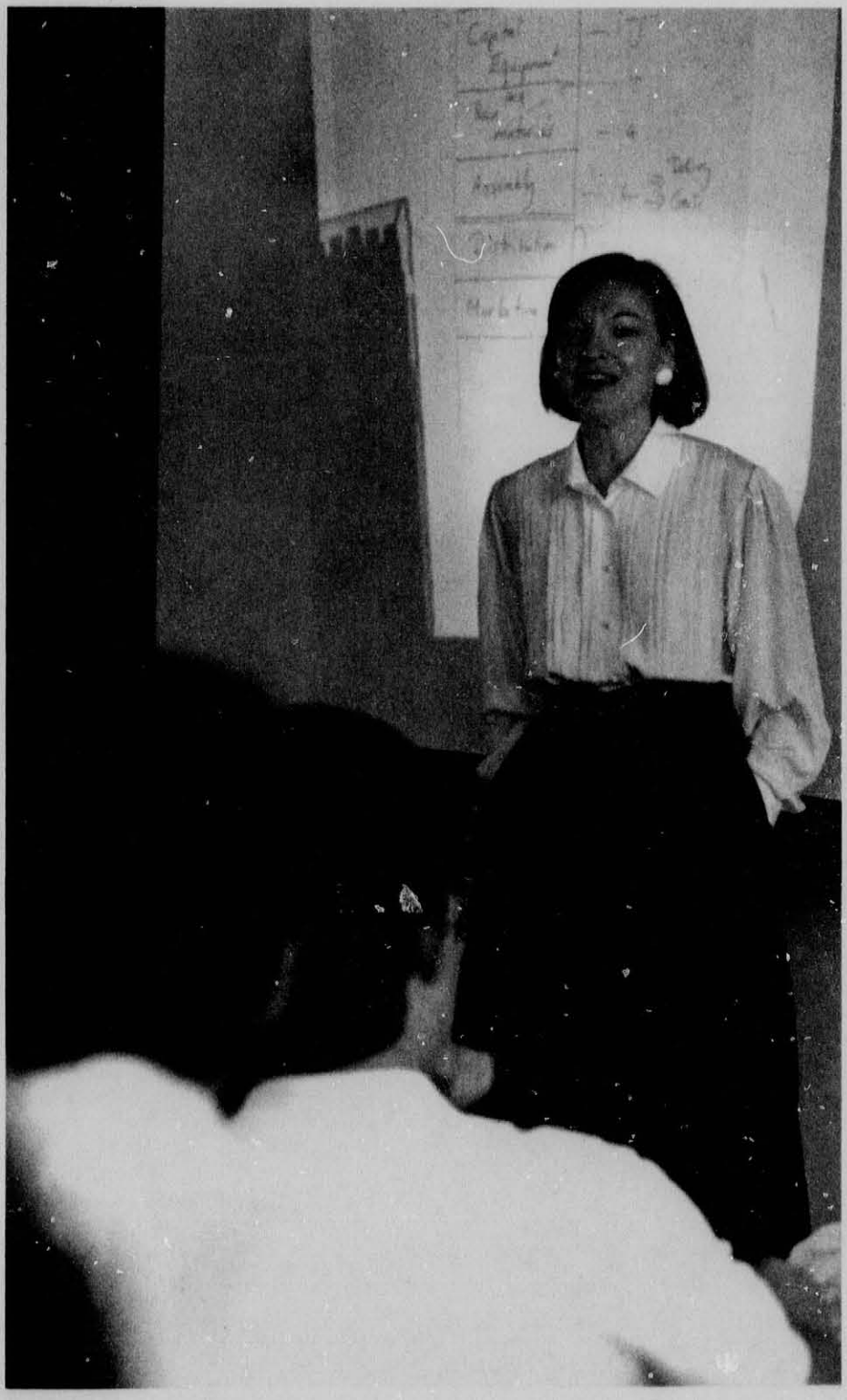
Inquiries

Additional information on the Program in Science, Technology, and Society may be obtained from Professor Kenneth Keniston, Room E51-110, MIT, Cambridge, Massachusetts 02139, (617) 253-4062.

For detailed descriptions of subjects in Science, Technology, and Society, see STS 001-901 in Chapter VIII.

Sloan School of Management

Management (Course 15)



The Sloan School of Management, founded in 1952 as the School of Industrial Management, is the outgrowth of a pioneering curriculum organized at MIT in 1914, which combined management and engineering education. Since those early years, Course XV, Management, has provided this unique pattern of education to MIT's undergraduates. During this period many of the Institute's most distinguished graduates made their reputations as managers and business leaders. However, the gift of Alfred P. Sloan, Jr., in 1952 was the landmark in establishing a new level and a broader scope in management education at MIT, and much of the story of management education at the Institute has been written since then.

The Sloan School now offers an undergraduate program leading to the Bachelor of Science in Management Science; graduate programs leading to the Master of Science in Management and the Doctor of Philosophy; a one-year Alfred P. Sloan Program in executive development leading to the Master of Science in Management; and a nine-week Program for Senior Executives in executive development. In addition, the Sloan School participates with the School of Engineering in the interdepartmental Management of Technology Program, leading to a Master of Science in the Management of Technology. Over the past several years the School has developed a large number of summer subjects designed primarily to meet the needs of practicing professionals in the various areas of the School's program.

The Sloan School has set as its mission the development and dissemination of knowledge for improving management in the context of a global economy with increasing technological competition and the need for more rapid organizational change. In its efforts, the School is committed to educating enterprise managers — men and women who have the will to manage and to risk, who can deal with complex systems, who have insight into themselves as well as others, who understand the total environment in which they live, and who continue to learn. In fulfilling this commitment, the School provides students with a solid grounding in the academic disciplines relevant to management — economics, mathematics, and the behavioral sciences — and develops their awareness of the multiple facets which characterize important management problems, from technical data to human factors. The School also endeavors to teach students to make decisions and to move decisively and responsibly in an increasingly complex world.

Sloan School of Management

The opportunities for such graduates in a society full of challenge, both social and technical, are substantial and growing in fields which include industrial management and the management of technology, health services, education, and public and urban affairs.

In addition to educating men and women for management, the Sloan School is equally committed to research directed at new understanding of and better solutions to management problems. Together, research and education are mutually reinforcing goals, and the School is confident of the continued impact of work done at MIT in the fields of management and management education.

Office of the Dean

Lester C. Thurow, Ph.D.
Gordon Y Billard Professor of Management and Economics
Dean

Arnoldo Cubillos Hax, Ph.D.
Alfred P. Sloan Professor of Management
Deputy Dean

Glen Lee Urban, Ph.D.
Dai-ichi Kangyo Bank Professor of Management
Deputy Dean

Professors

Thomas John Allen, Jr., Ph.D.
Gordon Y Billard Fund Professor of Management

Lotte Lazarsfeld Bailyn, Ph.D.
Professor of Organizational Psychology and Management

Arnold Irwin Barnett, Ph.D.
Professor of Operations Research and Management

Ernst R. Berndt, Ph.D.
Professor of Applied Economics

Gabriel Richard Bitran, Ph.D.
Professor of Management Science

John Carrington Cox, Ph.D.
Nomura Professor of Finance

Jay Wright Forrester, D.Eng.
Germeshausen Professor of Management

Stephen C. Graves, Ph.D.
Professor of Management Science
(On leave, fall)

John Richard Hauser, Sc.D.
Professor of Management Science

Arnoldo Cubillos Hax, Ph.D.
Alfred P. Sloan Professor of Management
Deputy Dean

Henry Donnan Jacoby, Ph.D.
Professor of Management

Gordon Mayer Kaufman, D.B.A.
Professor of Operations Research and Management

Thomas Anton Kochan, Ph.D.
Professor of Industrial Relations

Donald Roy Lessard, Ph.D.
Professor of International Management

John Dutton Conant Little, Ph.D.
George Maverick Bunker Professor of Management Science
(On leave)

Stuart Elliot Madnick, Ph.D.
Professor of Management Science

Thomas Lee Magnanti, Ph.D.
George Eastman Professor of Management Science
Codirector, Operations Research Center
Codirector, Leaders for Manufacturing Program

Robert Bruce McKersie, D.B.A.
Professor of Industrial Relations

Robert Cox Merton, Ph.D.
J.C. Penney Professor of Management

Stewart Clay Myers, Ph.D.
Gordon Y Billard Professor of Finance

J. D. Nyhart, J.D.
Professor of Management and Ocean Engineering

James Berger Orlin, Ph.D.
Professor of Management Science and Operations Research

Robert Stephen Pindyck, Ph.D.
Mitsubishi Bank Professor of Finance

Michael Joseph Piore, Ph.D.
Professor of Economics and Management

William Frank Pounds, Ph.D.
Professor of Management

Edward Baer Roberts, Ph.D.
David Sarnoff Professor of Management of Technology
(On leave)

Edgar Henry Schein, Ph.D.
Sloan Fellows Professor of Management

Richard Lee Schmalensee, Ph.D.
Professor of Management and Economics

Michael Stewart Scott Morton, D.B.A.
Professor of Management

Jeremy Frank Shapiro, Ph.D.
Professor of Operations Research and Management

Abraham J. Siegel, Ph.D.
Howard W. Johnson Professor of Management

Alvin John Silk, Ph.D.
Erwin H. Schell Professor of Management

Lester C. Thurow, Ph.D.
Gordon Y Billard Professor of Management and Economics
Dean, Sloan School of Management

Glen Lee Urban, Ph.D.
Dai-Ichi Kangyo Bank Professor of Management
Deputy Dean

John Eastin Van Maanen, Ph.D.
Professor of Organizational Psychology and Management

Eric Arthur von Hippel, Ph.D.
Professor of Management

Roy Elmer Welsch, Ph.D.
Professor of Statistics and Management Science
Codirector, Statistics Center

Associate Professors

John Stephen Carroll, Ph.D.
Associate Professor of Behavioral and Policy Sciences

Randall Davis, Ph.D.
Associate Professor of Management Science
Associate Director of Artificial Intelligence

John Joseph Donovan, Ph.D.
Associate Professor of Management Science
(On leave)

Robert Michael Freund, Ph.D.
Elisha Gray II Career Development Associate Professor of Management Science

Paul Healy, Ph.D.
Associate Professor of Management

John C. Henderson, Ph.D.
Associate Professor of Management Science

Chi-fu Huang, Ph.D.
Associate Professor of Finance

Peter Kempthorne, Ph.D.
Associate Professor of Management Science

Judith Ann Lachman, Ph.D.
Associate Professor of Law and Management

Andrew W. Lo, Ph.D.
Associate Professor of Finance
(On leave)

Thomas Wendall Malone, Ph.D.
Douglas Drane Career Development Associate Professor in Information Technology and Management

Paul Osterman, Ph.D.
Associate Professor of Management

Julio Jacobo Rotemberg, Ph.D.
Associate Professor of Applied Economics

Garth Saloner, Ph.D.
Associate Professor of Management and Economics

John David Sterman, Ph.D.
Associate Professor of Management

Thomas Martin Stoker, Ph.D.
Associate Professor of Applied Economics

Robert J. Thomas, Ph.D.
Associate Professor of Organizational Studies

Dorothy Eleanor Westney, Ph.D.
Mitsubishi Career Development Associate Professor in International Management

Assistant Professors

Deborah Gladstein Ancona, Ph.D.
Assistant Professor of Organizational Studies

Anantaram Balakrishnan, Ph.D.
Assistant Professor of Management

Dimitris Bertsimas, M.S.
Assistant Professor of Management

Ravi Bhushan, Ph.D.
Assistant Professor of Accounting

Wujin Chu, Ph.D.
Assistant Professor of Management Science

Michael A. Cusumano, Ph.D.
Assistant Professor of Management

Steven D. Eppinger, M.S.
Assistant Professor of Management Science

Charles Harry Fine, Ph.D.
Assistant Professor of Management Science

Kenneth A. Froot, Ph.D.
Ford International Untenured Professor
(On leave)

Rebecca Marta Henderson, B.S.
Assistant Professor of Management

Frank Robert Kardes, Ph.D.
Assistant Professor of Management Science

Chris F. Kemerer, Ph.D.
Assistant Professor of Management Science

Don Naphtali Kleinmuntz, Ph.D.
Assistant Professor of Organizational Studies

Lode Li, Ph.D.
Assistant Professor of Management Science

Richard M. Locke, M.A.
Assistant Professor of Management and Political Science

Lisa M. Lynch, Ph.D.
Assistant Professor of Industrial Relations

Deborah L. Marlino, Ph.D.
Assistant Professor of Management Science

Patricia Colleen O'Brien, Ph.D.
Assistant Professor of Management

Wanda Janina Orlikowski, M.Phil.
Assistant Professor of Management
(Spring)

John Emery Parsons, Ph.D.
Assistant Professor of Finance

Michael A. Rappa, Ph.D.
Assistant Professor of Management

James B. Rebitzer, Ph.D.
Assistant Professor of Management
(Spring)

Nancy Lin Rose, Ph.D.
Assistant Professor of Applied Economics

David Scharfstein, Ph.D.
Assistant Professor of Finance

Stephen Schrader, M.P.A.
Assistant Professor of Management
(Spring)

Michael Edmond Treacy, Ph.D.
Assistant Professor of Management Science
(On leave)

Marcie Jadine Tyre, M.B.A.
Assistant Professor of Management

Karl Ulrich, S.M.
Assistant Professor of Management

N. Venkatraman, Ph.D.
Assistant Professor of Management

Lawrence M. Wein, Ph.D.
Assistant Professor of Management Science

Visiting Professors

Miguel Angel Ariño, Ph.D.
Professor of Management Science

Avraham Beja, Ph.D.
Professor of Management

Jeffrey Lawrence Calley, Ph.D.
Professor of Management
(Fall)

Frank J. Fabozzi, Ph.D.
Professor of Accounting and Finance

Charles A. Holloway, Ph.D.
Professor of Management Science

Jan Karel Lenstra, Ph.D.
Professor of Management Science
(Fall)

Rajnish Mehra, Ph.D.
Professor of Finance

Norman Stanley Stearns, M.D.
Professor of Health Management

Thomas Vargish, Ph.D.
Professor of Management

William J. Qualls, D.B.A.
Associate Professor of Marketing

Antonio S. Mello, Ph.D.
Assistant Professor of Finance

Adjunct Professors

James Suren Hekimian, Ph.D.
Adjunct Professor of Management

Mary P. Rowe, Ph.D.
Adjunct Professor of Management

Senior Lecturers

Stan Neil Finkelstein, M.D.

Mel Horwitch, D.B.A.

Julian Keilson, Ph.D.

Richard Alexander MacKinnon, M.B.A.

Jeffrey Alan Meldman, Ph.D., J.D.
Associate Dean for Student Affairs

Russell W. Olive, D.B.A.
(Visiting, spring)

John Fralick Rockart, Ph.D.
Director, Center for Information Systems Research

Donald Barry Rosenfield, Ph.D.
Project Manager, Leaders for Manufacturing Program

Steven H. Star, D.B.A.

David O. Wood, B.S.

JoAnne Yates, Ph.D.

Lecturers

David R. Breakstone, M.A.
Arline H.Golden, Ph.D.
George Richard Heaton, Jr., J.D.
(Spring)
Gloria Schuck, Ph.D.
Achilles Venetoulias, M.S.
Alan F. White, S.M.

Administration

Sandra N. Anthony
Coordinator, Program for Senior Executives

Jean Frances Anderson, A.A.
Administrative Assistant

Jeffrey Allen Barks, Ph.D.
Associate Dean for Bachelor's and Master's Programs

Harriet Louise Barnett, M.Ed.
Master's Program Advisor

Donna Maria Behmer, M.Ed.
Associate Dean for Finance and Administration

Leo Francis Briody, B.S.
Systems Programmer III

Rosemary Brutico, B.A.
Managing Editor, *Sloan Management Review*

Olimpia E. Caceres, B.A.
Systems Programmer II

Sharon Ann Cayley, B.A.
Coordinator, Ph.D. Program

Eleanor Chin, B.A.
Administrative Assistant, Executive Education Programs

Sarah W. Cliffe, B.A.
Assistant Managing Editor, *Sloan Management Review*

Paula Budlong Cronin, S.M.
Director of Public Information
Editor, *MIT Management*

Hillary De Baun, B.A.
Undergraduate Program Administrator

Josephine Marie DiCicco
Faculty and Staff Records Manager

Anne L. Drazen, M.S.
Director of Information Systems

Ray Edwin Faith, Ph.D.
Manager, Sloan Computer Facility

Norma M. Gicka
Fiscal Manager

Peter P. Gil, Ph.D.
Director of Special Executive Programs

Mario L. Gnecco, M.S.
Director, Management of Technology Program

Charles R. Grader, Ph.D.
Associate Director of Executive Education and Director of the Program for Senior Executives

Lucinda Margaret Hill, B.S.
Master's Program Coordinator

Grace Charlotte Locke
Administrative Assistant

Maria C. Lucas, M.S.
Administrative Coordinator

Emily Frances Magazzu
Data Base Coordinator

John F. Maglio, S.M.
Microcomputer Network Administrator

Jennifer Mapes
Coordinator, Management of Technology Program

Judith Mason, B.A.
Area Coordinator

Ellen Nangle, A.S.
Administrative Assistant
Executive Education Programs

Edwin C. Nevis, Ph.D.
Director of Executive Program Development

Carol A. Peterson, B.A.
Circulation Manager, *Sloan Management Review*

Jan Austin Scott, M.B.A.
Area Coordinator

Linda Stantial, M.Ed.
Director of Master's Placement

Judith Stein, B.A.
Area Coordinator

Margaret Daniels Tyler, B.S.
Director of Master's Admissions

David A. Weber, S.M.
Associate Director of the Master's Program

Alan Frederick White, S.M.
Associate Dean for Executive Education Programs
Lecturer

Professors Emeriti

Sidney Stuart Alexander, Ph.D.
Professor of Management and Economics, Emeritus

William Filbert Bottiglia, Ph.D.
Professor of Management and Humanities, Emeritus

Edward Lindley Bowles, D.Sc.
Professor of Industrial Management, Emeritus

Edward Harry Bowman, Ph.D.
Professor of Management, Emeritus

Edward Pennell Brooks, D.C.S.
Professor of Industrial Management, Emeritus
Dean, Emeritus

David Durand, Ph.D.
Professor of Management, Emeritus

Daniel Mark Holland, Ph.D.
Professor of Finance, Emeritus
Senior Lecturer and Assistant to the Provost

Howard Wesley Johnson, LL.D.
Special Faculty Professor of Management, Emeritus

Franco Modigliani, D.Jr., D.Soc.Sci., LL.D.
Institute Professor, Emeritus
Professor of Finance and Economics, Emeritus

Leo Benjamin Moore, S.M.
Professor of Management, Emeritus

Charles Andrew Myers, Ph.D.
Professor of Industrial Relations
Sloan Fellows Professor of Management, Emeritus

Richard Dunlop Robinson, Ph.D.
Professor of Management, Emeritus

Eli Shapiro, Ph.D.
Alfred P. Sloan Professor of Management, Emeritus

Phyllis Ann Wallace, Ph.D.
Professor of Management, Emerita

Undergraduate Study

Bachelor of Science in Management Science
Course XV

The Sloan School of Management offers an undergraduate degree program based in the field of management science. It is particularly well suited to students who wish to understand problems of management within the context of fundamental disciplines and, where appropriate, with quantitative rigor and precision. The program provides a strong preparation for graduate study in management, while at the same time securing an advantageous market position for students seeking employment directly upon graduation.

In recent years, the field of management science has grown rapidly in conjunction with advances in computer technology, in methods for collecting and structuring large quantities of data, in mathematical programming, and in the building of sophisticated mathematical models. These advances have become increasingly applicable to the solving of difficult problems in business, government, and other public and private organizations. The Sloan School's undergraduate program develops necessary competence in the underlying disciplines of mathematical programming and modeling, statistics, and computer technology. It also provides a strong background in the associated disciplines of managerial psychology and economics. It then demonstrates applications from a variety of functional areas of management. Beyond this, each student selects an option (of four subjects) in one specialized area such as information systems, operations research, marketing research, or behavioral science.

A number of unrestricted electives is included in the curriculum and these can be devoted to a variety of career or personal objectives. Students who take subjects in additional functional areas of management can usually complete requirements of the Master of Science in Management in one year after completing the Bachelor of Science degree in Management Science. Substantial exposure to an area of physical science or engineering, in addition to an education in management, can be achieved by a technically oriented elective program. We encourage students who wish a broader general education to take additional subjects in the humanities, arts, and social sciences, and to consider adding a HASS minor. Appropriate selection of electives should permit a student to meet admission requirements of medical, law, or other graduate schools.

Inquiries

For additional information on the undergraduate curriculum and referral to appropriate faculty counselors, students may consult the Undergraduate Program Office, Sloan School of Management, Room E40-150, MIT, Cambridge, Massachusetts 02139, (617) 253-8614.

1
Students who have completed 15.001 are *not* required to take 14.01 and 14.02. Students who take both 14.01 and 14.02 may use one Restricted Elective, appropriately chosen, to count toward one of their Option Subjects.

2
15.351 and 15.664 cannot both be used to satisfy the Restricted Elective.

3
Students who have highly motivated interests may select options in other areas. Further information about options and the subjects they include is available in the Undergraduate Program Office (E40-150).

Bachelor of Science in Management Science
Course XV

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [2 subjects can be satisfied by 14.01 and 14.02 in the Departmental Program]	8
Science Distribution Requirement [2 subjects can be satisfied from among 6.041, 15.053, and 18.06 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 15.301 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	**84**
6.041 Probabilistic Systems Analysis, 12; 18.02	
14.01 Principles of Microeconomics[1], 9	
14.02 Principles of Macroeconomics[1], 9	
15.053 Introduction to Management Science, 12; 18.02, *18.06*	
15.075 Applied Statistics, 9; 6.041**	
15.301 Managerial Psychology Laboratory, 12	
15.501 Introductory Financial Accounting, 9	
18.06 Linear Algebra, 12; 18.02	
Restricted Electives:	**63 to 84**
One of the following four subjects:	
1.00 Introduction to Computers and Engineering Problem Solving, 12	
2.10 Elementary Programming and Machine Computation, 9	
6.001 Structure and Interpretation of Computer Programs, 15	
15.564 Management Information Technology I, 12; 2.10**	
Two of the following five subjects:[2]	
15.351 Introduction to Technological Innovation Management, 9	
15.412 Financial Management II, 12; 15.501	
15.664 Management of Human Resources, 9	
15.761 Operations Management, 9; 15.053**, 6.041**	
15.812 Marketing Management, 9; 6.041**	
Option Subjects:	
Four specified subjects in one of the following options: Information Systems, Operations Research, Marketing Research, Behavioral Science, 36 to 48[3]	
Units in Departmental Program that also satisfy the General Institute Requirements	**(54)**
Unrestricted Electives	**66-87**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Graduate Study

Bachelor of Science in Management Science
Course XV

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement [can be satisfied by 6.041, 15.053, and 18.06 in the Departmental Program]	
Laboratory Requirement [can be satisfied by 15.301 in the Departmental Program]	

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects:		78
6.041	Probabilisti c Systems Analysis, 12; 18.02	
15.001	Managerial Economics[1], 12	
15.053	Introduction to Management Science, 12; 18.02, *18.06*	
15.075	Applied Statistics, 9; 6.041*	
15.301	Managerial Psychology Laboratory, 12	
15.501	Introductory Financial Accounting, 9	
18.06	Linear Algebra, 12; 18.02	

Restricted Electives:		63 to 84
One of the following four subjects:		
1.00	Introduction to Computers and Engineering Problem Solving, 12	
2.10	Elementary Programming and Machine Computation, 9	
6.001	Structure and Interpretation of Computer Programs, 15	
15.564	Management Information Technology I, 12; 2.10*	
Two of the following five subjects:[2]		
15.351	Introduction to Technological Innovation Management, 9	
15.412	Financial Management II, 12; 15.501	
15.664	Management of Human Resources, 9	
15.761	Operations Management, 9; 15.053*, 6.041*	
15.812	Marketing Management, 9; 6.041*	

Option Subjects:

Four specified subjects in one of the following options: Information Systems, Operations Research, Marketing Research, Behavioral Science, 36 to 48[3]

Unrestricted Electives	**66-87**
Total Units Required for the S.B. Degree	**360**

*Alternate prerequisites are listed in the subject description.

1
Students may take 14.01 or 14.02 or both in place ot 15.001.
2
15.351 and 15.664 cannot both be used to satisfy the Restricted Elective.
3
Students who have highly motivated interests may select options in other areas. Further information about options and the subjects they include is available in the Undergraduate Program Office (E40-150).

The Sloan School of Management offers opportunity for graduate work leading to the degrees of Master of Science in Management and Doctor of Philosophy.

Entrance Requirements for Graduate Study

Applications are welcome from college graduates in all areas of concentration — the humanities, the social sciences, the physical sciences, and engineering — but matriculants must have completed formal courses in differential and integral calculus and in macro- and microeconomics. The minimum level of preparation is normally a one-year course in economic theory and a one-year course in calculus. If these subjects have not been taken in a previous academic program, they may be covered by formal courses prior to enrollment in anticipation of diagnostic examinations given at the beginning of the first term at the Sloan School.

All applicants, including those from foreign countries, must take the Graduate Management Admission Test (GMAT). Information is available from the Graduate Management Admission Council, Educational Testing Service, Princeton, New Jersey 08541. The January test is the latest one appropriate for admission the following September. GRE scores are not required and may not be substituted. Applicants whose native language is not English, and who have not received a degree from an English-language university, must take the Test of English as a Foreign Language (TOEFL).

Master of Science in Management

Degree candidates are admitted in September to a program of study extending over two academic years.

The two-year Sloan Master's Program offers students with or without previous work experience a comprehensive education in management, as well as the opportunity to develop competence in a particular area of interest that may lead to positions of either general executive responsibility or technical leadership.

The program follows three distinguishable though closely related lines: theoretical studies, applied studies, and practical exposure.

Theoretical studies aim to improve the student's understanding of certain fundamental phenomena and relationships that characterize the changing world in which managers must operate. The principal fields covered by these studies are economics, behavioral science, and quantitative methods of analysis. The Sloan School was a pioneer in fitting these rigorous disciplinary subjects into the curriculum of a graduate business school. Although by now many comparable schools have followed this lead, the School continues to be distinguished from most of its counterparts by the importance it attaches to developing the student's basic powers of analysis and by the emphasis it places on understanding the economic and social environment in which organizations operate. This inclusion of rigorous work in the basic disciplines of management has served the graduates of the School well in dealing with newly emerging and increasingly complex professional challenges.

Applied studies, which occupy the bulk of the student's time in the second year of the master's program, link the theoretical studies to the practical problems faced by managers. The Sloan School offers an unusually wide range of applied fields, the principal ones being Accounting; Applied Economics; Corporate Strategy, Policy, and Planning; Finance; Health Care Management; Human Resource Management; Industrial Relations; International Management; Management Information Systems; Management of Technological Innovation; Marketing; Operations Management; Operations Research and Statistics; Organization Studies; and System Dynamics. Many subjects are taught in each of these fields, and the curriculum allows students considerable choice. This flexibility enables students to construct either a general program that introduces them to many of the applied fields, or a specialized program that permits them to study one or two of the applied fields in depth. Students are thus able to design broad programs if they are interested in immediate entry into general management careers, or more specialized ones if they seek expertise as a means to higher-level management responsibility. In either case, students acquire basic knowledge and skills essential to general management.

Practical exposure to management takes place in the Sloan School through a variety of activities. Students in the master's program are expected to spend the intervening summer working in some activity that will contribute to their understanding of and effectiveness in dealing with management problems. During the academic year, some master's candidates work as paid research assistants for members of the faculty, or become involved with them in the consulting activities that they carry on for government, firms, and other public and private organizations. In addition, many students choose topics for their master's theses that involve research in the practice of management in particular organizations, industries, or sectors.

The thesis, an MIT requirement for the Master of Science degree, is a major component of the Sloan Master's Program. It offers students, under the supervision of their faculty advisors, the opportunity to practice newly acquired management skills in the exploration of a single topic of particular interest. Each thesis normally represents the original contribution of a single student, although in the case of collaborative research, joint theses are also encouraged. A third dimension to the thesis concept is the "project" thesis, in which faculty members engaged in research activities that lend themselves to teamwork may offer groups of students the opportunity to explore portions of the overall study, with each student reporting on a specific phase.

Master of Science in Management and Engineering

Students hoping to combine graduate education in management and engineering, in order to pursue a career within the manufacturing industry, may apply for the 24-month Leaders for Manufacturing Program. This rigorous program combines subjects in advanced technology with management subjects, and involves on-site research work and close cooperation with manufacturing companies. The Program is offered jointly through the Sloan School of Management and the Departments of Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, and Mechanical Engineering in the School of Engineering. General requirements and application procedures are described in Chapter VI.

Doctor of Philosophy

The purpose of the Sloan School's doctoral program is to prepare students for careers in teaching and research or for nonacademic positions requiring advanced research and analytical capabilities. The doctoral program provides the opportunity to combine in-depth work in theory with work in broadly defined "applied" or "functional" fields.

A candidate entering with a bachelor's degree should be able to complete the program in four years. The first year is devoted to work in the "basic disciplines" of management and to preliminary work in the student's major and minor fields. The second year is primarily devoted to the major and minor fields. Finally, one to two years are required for the doctoral dissertation. A candidate entering with an advanced degree may be able to finish in less time depending on previous experience in research.

Breadth Requirement. The basic disciplines referred to above are behavioral science, economics, and quantitative methods. Students may demonstrate competence in each of these "breadth" areas by passing a qualifying examination or by successfully completing subjects specified by the Ph.D. Committee. Entering students with formal preparation in these disciplines are encouraged to take the qualifying examinations in September, when they enroll. Passing these will expedite progressing through the program.

Major and Minor Fields. Candidates must master the literature, theory, and application of a major field of concentration as well as a minor field. Successful completion of this requirement is determined by General Examinations. The major fields currently available in the Sloan School are the following (although individually constructed majors are possible):

Accounting
Managerial Economics
Finance
Industrial Relations
International Management
Management Information Systems
Management of Technological Innovation
Marketing
Operations Management
Operations Research and Statistics
Organization Studies
Strategy and Policy
System Dynamics

Most doctoral students enter the program with a fairly clear idea in mind of a major field of concentration, and it is typically an "applied field." An appropriate minor field is then selected — a theoretical discipline that provides a foundation for research in the major field. The following are examples of natural and usual combinations:

Major Field	Minor Field
Finance	Economics
Industrial Relations	Behavioral Science
Marketing	Statistics
Operations Management	Operations Research
Organization Studies	Behavioral Science
System Dynamics	Economics

There are no rigid subject requirements for the major and minor fields. There are normal groups of subjects for the standard fields, but substitutions of other subjects and independent study are possible. Regardless of the major and minor fields chosen, a plan of study designed to prepare the student for General Examinations is worked out by the student and his or her faculty advisor(s) and submitted to the Ph.D. Committee for approval at the beginning of the spring term in the student's first year.

General Examinations normally are taken in September of the third year of study, after completion of the breadth requirement, major and minor field course work, and a research paper (see below). The exact form of General Exams varies from area to area and may involve written examinations, critiques of research papers, or review papers on prescribed topics. In all cases, the last stage is an oral examination covering both major and minor fields.

Research. The Sloan School is deeply committed to research, and the philosophy and structure of the Ph.D. program reflect this professional commitment. There are two separate research requirements: the research paper and the thesis.

A substantial part of the student's work in the latter half of the first year and in the second year is devoted to an independent research project. The topic, design, and execution of the project are left to the student, while advice and criticism are provided by a research advisor and other interested faculty. Upon completion of the project, the student prepares a document that, after the evaluation and approval of faculty members, is published in the Sloan School's Working Paper Series.

The doctoral dissertation consists of significant scholarly research in some area of management. Close working relationships with senior faculty are established early so that the thesis can be defined as a manageable project as early as possible. Candidates typically require one to two years of full-time work to complete their theses.

Teaching Apprenticeship

Since the graduates of the doctoral program are almost invariably involved in teaching, whether in a university or in other organizational settings, there is a Teaching Apprenticeship requirement for the degree. Each candidate is given partial responsibility for conducting a Sloan School subject. The apprenticeship offers an opportunity for working closely with a faculty member who can provide

constructive feedback and counsel. The apprenticeship is normally undertaken by the third year of study, after General Examinations have been passed, but may be completed earlier if a suitable teaching opportunity is available.

Language Requirement

There is no language requirement in the Sloan School's doctoral program, although in some cases the student and his or her advisor decide that further study of a foreign language is necessary if the student is to work effectively in his or her major field. This is usually true, for example, in the field of International Management.

Fellowships, Teaching and Research Assistantships

Except for some limited funds to aid needy minority students, fellowships for graduate study in management are given only to doctoral degree candidates. All graduate students who have completed a year (or sometimes a term) of graduate study in the Sloan School are eligible to apply for the approximately 100 part-time research and teaching assistantships available each year.

Inquiries

For master's information, call (617) 253-3730; for doctoral information, call (617) 253-7188. Additional information concerning graduate programs, admissions, and financial aid, may be obtained from the Graduate Programs Office, Room E52-112, Sloan School of Management, MIT, Cambridge, Massachusetts 02139.

Programs for Executive Education in Management

Alfred P. Sloan Fellows Program

Each year, the Alfred P. Sloan Fellows Program admits approximately 50 mid-career executives who have demonstrated potential for filling positions of more general and senior management responsibility in the future. These men and women are sponsored by industry, government, and other organizations (or they may apply independently). Approximately one-third of the participants selected are from abroad. The 12-month Program, providing regular classroom work plus close contact with business and government leaders here and abroad, is taken in conjunction with the regular graduate program and leads to the degree of Master of Science in Management.

In 1975, the Sloan School initiated a Health Management Option within the Sloan Fellows Program, aimed at mid-career to senior-level health-care practitioners, educators, researchers, and administrators. These health professionals participate fully in all aspects of the Sloan Fellows Program.

MIT Program for Senior Executives

The Program for Senior Executives is an intensive nine-week course of study designed for the senior-level executive already in or preparing for a position of major managerial responsibility. Enrollment in this nondegree program, offered in the fall and spring of each year, is limited to groups of 50. A one-week trip to Washington, DC, to visit policymakers in the Federal government, is an integral part of the Program.

Master of Science in Management of Technology

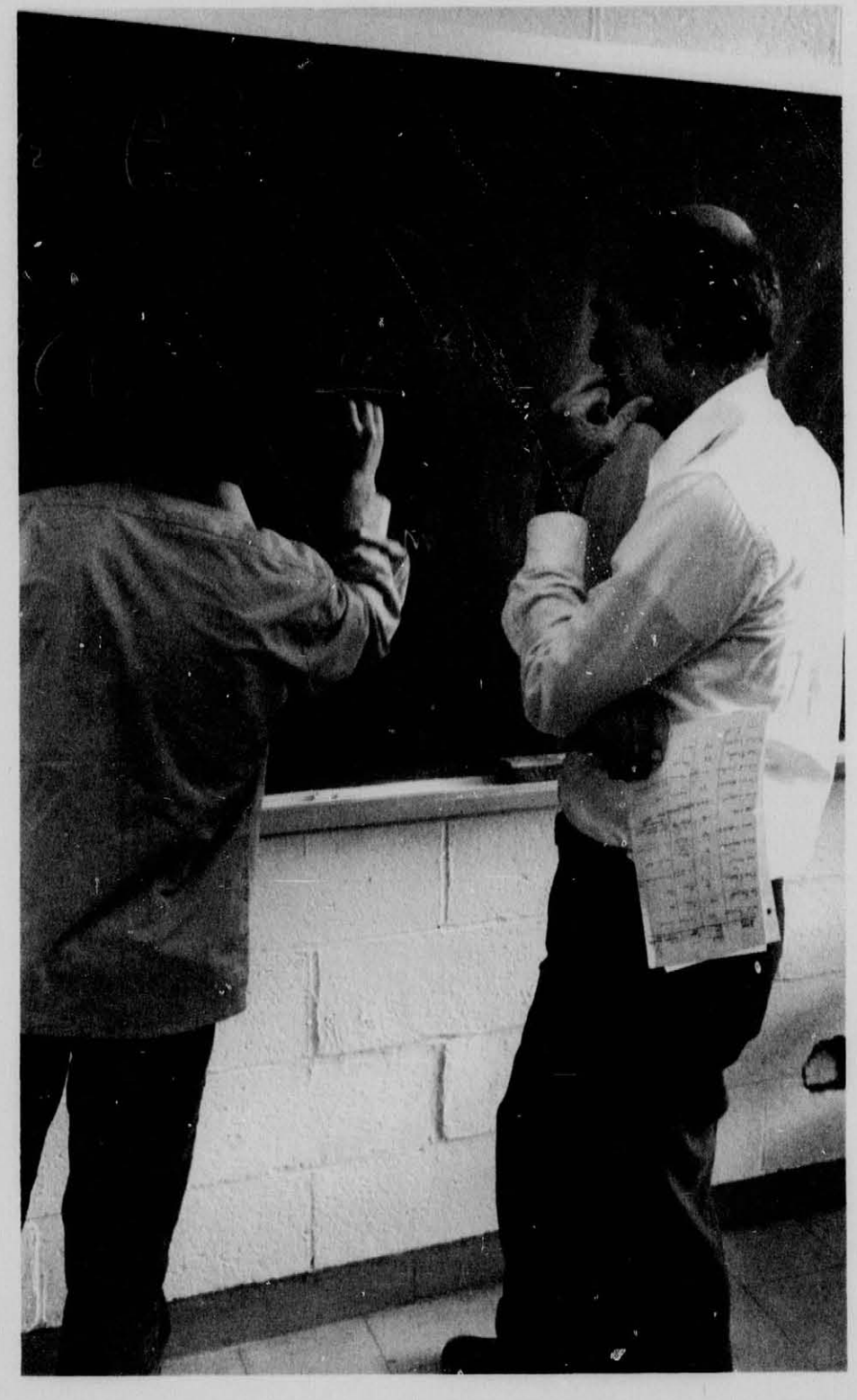
Offered jointly by the MIT Schools of Engineering and Management, this is a twelve-month executive education program leading to the degree of Master of Science in the Management of Technology. The program is designed for men and women with engineering or science backgrounds — and five to ten years of work experience — who are facing increasing responsibilities on the technical side of their organization. The curriculum aims at preparing managers who can help bring advances in technology to the marketplace in the form of new products and services, and new manufacturing processes.

Inquiries

Detailed information about these programs may be obtained from the Executive Education Programs Office, Room E52-126, Sloan School of Management, MIT, Cambridge, Massachusetts 02139, (617) 253-7166.

School of Science

Biology (Course 7)
Chemistry (Course 5)
Earth, Atmospheric, and Planetary Sciences (Course 12)
Mathematics (Course 18)
Physics (Course 8)
Program in Applied Biological Sciences (Course 20)



Our continually increasing understanding of the physical and biological worlds opens up new possibilities of applications for the benefit of humanity, and helps us to better appreciate the world in which we live. Today we are increasingly dependent on science for the knowledge that allows us to solve practical problems and to find better ways of providing for the world's needs.

Training in science provides a firm basis for many types of careers. Scientific training is not only needed for teaching and research but also provides an opportunity to enter many other professions. Students with bachelor's degrees in science often go on to medical school, law school, business school, and other professional schools, including engineering. Science has, of course, contributed in the most fundamental way to the advancement of technology, and technology has contributed importantly to the advancement of science. At MIT, the relationships between science and technology are especially close and mutually reinforcing.

The sciences and mathematics form an intellectual continuum, but for administrative purposes they are divided into five departments at MIT. There are many interrelations between the programs of these departments, and the interdepartmental laboratories help to form a bridge between fields and to provide contact with applications.

At MIT, the biological sciences are represented by a wide range of disciplines including cell biology, microbiology, biochemistry, immunology, molecular biology, cancer biology, metabolism and human nutrition, toxicology, and biochemical engineering. The biological sciences have undergone tremendous changes since the discovery of the structure of deoxyribonucleic acid (DNA). The Center for Cancer Research and the Cell Culture Center are interdepartmental laboratories that are closely related to the Department of Biology. The Whitehead Institute for Biomedical Research is affiliated with MIT, and its faculty members hold appointments in the Department of Biology. The Whitaker College of Health Sciences, Technology, and Management has joint programs with the School of Science.

The physical sciences deal with the widest range of physical phenomena — from the shortest distances between particles inside the nucleus to the greatest distances over which we learn of the structure and substance of the universe from astronomy and astrophysics.

In physics at MIT, the four main areas are astrophysics; experimental nuclear and particle physics; solid state, laser, plasma, and atomic physics; and nuclear and particle theory. A great deal of physics research is carried out in the various interdepartmental laboratories listed here.

In the Department of Chemistry, research and education are carried out in organic, inorganic, physical, analytical, biological, and biophysical chemistry, and in chemical physics. These sciences are heavily involved in industry, and many graduates find their careers in applications as well as in research.

The earth sciences include geology, geochemistry, geophysics and planetary science, and meteorology and physical oceanography. The increased understanding of plate tectonics has revolutionized our views of the past and current changes in the structure of the earth. The increased use of computers in atmospheric and oceanographic models has revolutionized our understanding of circulation. The Wallace Astrophysical Observatory and the Wallace Geophysical Observatory provide opportunities for education and research, as do various interdepartmental laboratories. The joint doctoral program with the Woods Hole Oceanographic Institution provides opportunities to be involved in oceanographic research.

Mathematics provides a base and language for all types of research and is an area of active research itself in both the discovery of new mathematics and in applying mathematics in new ways to important applied problems. Pure mathematics is of interest in its own right, and it always has led in unexpected ways to a better understanding of the world. The core of the program in applied mathematics is concerned with the mathematical formulations of propagation, stability, optimization, cybernetics, statistics, and random processes.

The science departments and the related interdepartmental laboratories offer many opportunities for undergraduate research through the Undergraduate Research Opportunities Program. Through this program, students obtain firsthand research experience in fields that interest them, and learn in a different environment from the classroom or instructional laboratory. The Undergraduate Seminar Program provides study and associations with faculty members in smaller and less formal groups.

The School of Science also is involved in providing parts of the general education of undergraduate students through the Science Requirement subjects, Science Distribution subjects, and Laboratory subjects.

Interdisciplinary laboratories and centers associated with the School include the following:

Francis Bitter National Magnet Laboratory

Cell Culture Center

Center for Cancer Research

Center for Materials Science and Engineering

Center for Space Research

Clinical Research Center

Energy Laboratory

George Russell Harrison Spectroscopy Laboratory

Haystack Observatory

Laboratory for Computer Science

Laboratory for Nuclear Science

Lincoln Laboratory

Plasma Fusion Center

Research Laboratory of Electronics

Whitaker College of Health Sciences, Technology, and Management

Detailed descriptions of these laboratories and centers may be found in Chapter VI.

Office of the Dean

Gene M. Brown, Ph.D.
Professor of Biochemistry
Dean

Evelyn L. Pérez, B.A.
Assistant Dean for Personnel Administration

Charlene M. Placido, B.A.
Assistant Dean for Financial Administration

Judith M. Gooch, B.A.
Director of Development for the School of Science

School Professors Without Departmental Affiliation

Hamish Nisbet Munro, M.B., D.Sc.
Adjunct Professor of Physiological Chemistry

Nevin Stewart Scrimshaw, Ph.D., M.D., M.P.H.
Institute Professor

Vernon R. Young, Ph.D., D.Sc.
Professor of Nutritional Biochemistry
Clinical Research Center

Department of Biology

Maurice Sanford Fox, Ph.D.
Lester Wolfe Professor of Molecular Biology
Head of the Department

Richard Olding Hynes, Ph.D.
Professor of Biology
Associate Department Head

Professors

David Baltimore, Ph.D.
Professor of Microbiology
Director, Whitehead Institute for Biomedical Research

David Botstein, Ph.D.
Earle A. Griswold Professor of Genetics
(On leave)

Gene M. Brown, Ph.D.
Professor of Biochemistry
Dean, School of Science

Arnold Lester Demain, Ph.D.
Professor of Industrial Microbiology

Herman Nathaniel Eisen, M.D.
Whitehead Institute Professor of Immunology

Gerald R. Fink, Ph.D.
Professor of Genetics
American Cancer Society Research Professor of Genetics at the Whitehead Institute for Biomedical Research

Malcolm Lawrence Gefter, Ph.D.
Professor of Biochemistry

Nancy Haven Hopkins, Ph.D.
Professor of Biology

H. Robert Horvitz, Ph.D.
Professor of Biology

David Evan Housman, Ph.D.
Professor of Biology

Vernon Martin Ingram, Ph.D., D.Sc.
Professor of Biochemistry

Rudolf Jaenisch, M.D.
Professor of Biology

Har Gobind Khorana, Ph.D.
Alfred P. Sloan Professor of Biology and Chemistry

Jonathan Alan King, Ph.D.
Professor of Biology

Harvey Franklin Lodish, Ph.D.
Professor of Biology

Irving M. London, M.D.
Grover M. Hermann Professor of Health Sciences and Technology
Professor of Biology and Medicine

Boris Magasanik, Ph.D.
Jacques Monod Professor of Microbiology

Mary Lou Pardue, Ph.D.
Professor of Biology

Sheldon Penman, Ph.D.
Professor of Cell Biology

Uttam Lal RajBhandary, Ph.D.
Professor of Biochemistry

Alexander Rich, M.D.
Professor of Biophysics
William Thompson Sedgwick Professor of Biology

Phillips Wesley Robbins, Ph.D.
American Cancer Society Professor of Biochemistry

Robert Daniel Rosenberg, M.D., Ph.D.
Professor of Medicine and Biology

Robert Thomas Sauer, Ph.D.
Professor of Biochemistry

Paul Reinhard Schimmel, Ph.D.
Professor of Biochemistry and Biophysics

Phillip Allen Sharp, Ph.D.
John D. MacArthur Professor of Biology
Director, Center for Cancer Research

Ethan Royal Signer, Ph.D.
Professor of Biology

Anthony John Sinskey, Sc.D.
Professor of Applied Microbiology

Frank Solomon, Ph.D.
Professor of Biology

Lisa Amelia Steiner, M.D.
Professor of Immunology

Susumu Tonegawa, Ph.D.
Professor of Biology

Annamaria Torriani, Ph.D.
Professor of Biology

Alexander Jacob Varshavsky, Ph.D.
Professor of Biology

Graham Charles Walker, Ph.D.
Professor of Biology

Robert Allen Weinberg, Ph.D.
Professor of Biology

Associate Professors

Steven J. Burden, Ph.D.
Thomas D. and Virginia W. Cabot Career Development Associate Professor of Biology

Leonard Pershing Guarente, Ph.D.
Associate Professor of Biology

Monty Krieger, Ph.D.
Latham Family Career Development Associate Professor of Molecular Genetics

Ronald Davies Graham McKay, Ph.D.
Associate Professor of Neurobiology

Richard Charles Mulligan, Ph.D.
Associate Professor of Molecular Biology

William G. Quinn, Ph.D.
Associate Professor of Neurobiology

David Henri Raulet, Ph.D.
Robert A. Swanson Associate Professor in the Life Sciences

H. Earl Ruley, Ph.D.
Associate Professor of Biology

Richard Allen Young, Ph.D.
Associate Professor of Biology

Assistant Professors

Marie B. Chow, Ph.D.
Assistant Professor of Biology

Brent Hartman Cochran, Ph.D.
Assistant Professor of Biology

Alan Davis Grossman, Ph.D.
Assistant Professor of Biology

Peter S. Kim, Ph.D.
Assistant Professor of Biology

Arthur Douglas Lander, Ph.D.
Edward J. Poitras Assistant Professor in Human Biology and Experimental Medicine

Ruth Lehmann, Ph.D.
Assistant Professor of Biology

Kim A. Lewis, Ph.D.
Assistant Professor of Biology

Paul Thomas Matsudaira, Ph.D.
Assistant Professor of Biology

Barbara Jean Meyer, Ph.D.
Whitehead Institute Career Development Assistant Professor of Biology

Terry L. Orr-Weaver, Ph.D.
Assistant Professor of Biology

David Conrad Page, M.D.
Assistant Professor of Biology

Donald C. Rio, Ph.D.
Assistant Professor of Biology

Hee-Sup Shin, M.D., Ph.D.
Assistant Professor of Biology

Hermann Steller, Ph.D.
Assistant Professor of Neurobiology

Administrative Officer

Cynthia D. Kowal, B.A.

Assistant to the Department Head

Maija K. Ahlquist, B.A.

Senior Lecturer

Leonard S. Lerman, Ph.D.

Principal Research Scientist

Joan Lucia Suit, Ph.D.

Research Scientists

David Beeler, M.S.
N. Narayana Rao, Ph.D.
Katherine Wan, Ph.D.

Postdoctoral Associates

Ezra S. Abrams, Ph.D.
Gary Barsomian, Ph.D.
Patricia Benjamin, Ph.D.
Olivia Bermingham-McDonogh, Ph.D.
Leslie Bloom, Ph.D.
Chung Mong Chen, Ph.D.
Ariane DeAgostini, Ph.D.
Harold J. Drabkin, Ph.D.
Daniel J. Finley, Ph.D.
Christopher Francklyn, Ph.D.
Christin Frederick, Ph.D.
Steven Hahn, Ph.D.
Alan G. Herbert, Ph.D.
Ya-Ming Hou, Ph.D.
Robert W. Jackman, Ph.D.
Brian H. Johnston, Ph.D.
Tetsuhito Kojima, M.D.
Chan Ping Lee, Ph.D.
Ky Lowenhaupt, Ph.D.
Anna Mitraki, Ph.D.
Jeffrey Nickerson, Ph.D.
Soon Jae Park, Ph.D.
Peter Prevelige, Ph.D.

Department of Biology

(Course 7)

Undergraduate Study

Linda S. Reidl, Ph.D.
Jasmit Sarrowa, Ph.D.
Shashi Sharma, Ph.D.
Jim O. Vigoreaux, Ph.D.
Robert J. Villafane, Ph.D.
Daniel B. Wacks, Ph.D.
Verena M. Weiss, Ph.D.
Xiaohang Yang, Ph.D.
Corinne Yoshihara, Ph.D.

Professors Emeriti

Eugene Bell, Ph.D.
Professor of Biology, Emeritus

John Machlin Buchanan, Ph.D., D.Sc.
Professor of Biochemistry, Emeritus

Jerome Ysrael Lettvin, M.D.
Professor of Communications Physiology and Electrical and Bioengineering, Emeritus

Salvador Edward Luria, M.D., D.Sc.
Institute Professor, Emeritus

Francis Otto Schmitt, Ph.D., Sc.D.
Institute Professor, Emeritus
Professor of Biology, Emeritus

Irwin Whiting Sizer, Ph.D.
Professor of Biochemistry, Emeritus

The Department of Biology offers undergraduate, graduate, and postdoctoral training in basic biology, and in a variety of biological fields of specialization. The quantitative aspects of biology, including molecular biology, biochemistry, genetics, and cell biology, represent the core of the program. Students in the Department are encouraged to acquire a solid background in the physical sciences not only to master the applications of mathematics, physics, and chemistry to biology, but also to develop an integrated scientific perspective. The various programs, emphasizing practical experimentation, combine a minimum of formal laboratory exercises with ample opportunities for research work both in project-oriented laboratory subjects and in the Department's research laboratories. Students at all levels are encouraged to acquire familiarity with advanced research techniques and to participate in seminar activities.

Bachelor of Science in Life Sciences
Course VII

Two programs are offered leading to the Bachelor of Science in Life Sciences. The curriculum is designed to prepare students for a professional career in the area of the biological sciences. Graduates of this program are well prepared for positions in industrial or research institutes. However, experience has shown that most graduates probably will choose to continue their education at graduate schools in order to obtain a Ph.D. in biochemistry, microbiology, genetics, biophysics, cell biology, or physiology, followed by research or teaching in one of these areas. The undergraduate curriculum is also excellent preparation for students who wish to continue their education toward an M.D., particularly if their career plans include laboratory investigations bearing on human disease.

Bachelor of Science
Course VII-A

Course VII-A is designed for students who wish to obtain a background in the life sciences as preparation for careers without laboratory research such as medicine, graduate study of psychology, or management studies. This program, leading to the S.B., does not require 18.05 or a 24-unit laboratory subject, and allows 96 units in unrestricted electives so that students can plan their programs to suit their particular goals. Further details may be obtained from the Department.

Additional information regarding undergraduate academic programs, research opportunities, admissions, financial aid, etc. may be obtained from Biology Headquarters, Undergraduate Secretary, Room 56-511, Cambridge, Massachusetts 02139, (617) 253-4718.

Bachelor of Science in Life Sciences
Course VII-B

The undergraduate curriculum in Applied Biology (Course VII-B) is available to students who entered MIT prior to 1987. The curriculum emphasizes interdisciplinary laboratory and class experience in the physical and biological sciences. While required to perform only 24 units of research (which may lead to a S.B. thesis), most undergraduates work for three or more terms, plus one or two summers on their independent research projects.

Students should use their elective courses for more advanced subjects in their field and for additional study in basic subjects offered in various departments. Serious students should consider several subjects beyond the minimum requirements, such as 18.03 Differential

Equations, 8.03 Physics III, a third term of 5.43 Organic Chemistry, computer programming, and additional topics in physical chemistry.

Additional information on VII-B degree requirements may be obtained from Professor Marie B. Chow in the Department of Biology, Room 56-217, (617) 253-5393.

Bachelor of Science in Life Sciences Course VII

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 5.12 and either 7.01 or 7.05 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 7.011 in the Departmental Program][1]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	111
5.11 Principles of Chemical Science,[2] 12	
5.12 Organic Chemistry I, 12; 5.11	
5.60 Chemical Thermodynamics, 12; *18.02*	
7.01 General Biology,[3] 12	
7.011 Introduction to Experimental Biology, 15; 7.01 or 7.05	
7.03 Genetics, 12	
7.05 General Biochemistry, 12; 5.12	
7.08 Cell and Molecular Biology, 12; 7.03, 7.05	
18.05 Introduction to Probability and Statistics, 12; 18.01	
Restricted Electives:	60
Three 12-unit subjects offered by the Department of Biology for which 7.03 and/or 7.05 are prerequisites.	
One of the following three subjects:	
7.031 Experimental Microbial Genetics, 24; 7.011, 7.03, 7.05	
7.15 Experimental Molecular Biology: Biotechnology I, 24; 7.011, 7.03, 7.05	
7.16 Experimental Molecular Biology: Biotechnology II, 24; 7.011, 7.03, 7.05	
Units in Departmental Program that also satisfy the General Institute Requirements	(39)
Unrestricted Electives	48
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.

1
Either 7.011 or 5.311 satisfies the Institute Laboratory Requirement. However, both or their equivalent are required in order to satisfy medical school entrance requirements.
2
Students who take 5.11 to fulfill the General Institute Requirement for Chemistry must take 12 additional units of Unrestricted Electives.
3
An additional restricted elective may be substituted for 7.01.

Bachelor of Science in Life Sciences Course VII

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 5.11, 5.12, and either 7.01 or 7.05 in the Departmental Program[1]	
Laboratory Requirement can be satisfied by 7.011 in the Departmental Program[2]	

Departmental Program	
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	111
5.11 Principles of Chemical Science,[1] 12	
5.12 Organic Chemistry I, 12; 5.11	
5.60 Chemical Thermodynamics, 12; *18.02*	
7.01 General Biology,[3] 12	
7.011 Introduction to Experimental Biology, 15; 7.01 or 7.05	
7.03 Genetics, 12	
7.05 General Biochemistry, 12; 5.12	
7.08 Cell and Molecular Biology, 12; 7.03, 7.05	
18.05 Introduction to Probability and Statistics, 12; 18.01	
Restricted Electives:	60
Three 12-unit subjects offered by the Department of Biology for which 7.03 and/or 7.05 are prerequisites.	
One of the following three subjects:	
7.031 Experimental Microbial Genetics, 24; 7.011, 7.03, 7.05	
7.15 Experimental Molecular Biology: Biotechnology I, 24; 7.011, 7.03, 7.05	
7.16 Experimental Molecular Biology: Biotechnology II, 24; 7.011, 7.03, 7.05	
Unrestricted Electives	60
Total Units Required for the S.B. Degree	363

1
Students who take 5.11 to fulfill the General Institute Requirement for Chemistry must take 12 additional units of Unrestricted Electives.
2
Either 7.011 or 5.311 satisfies the Institute laboratory requirement. However, both or their equivalent are required in order to satisfy medical school entrance requirements.
3
An additional restricted elective may be substituted for 7.01.

Graduate Study

The Department of Biology offers graduate work leading to the Doctor of Philosophy. Study may be pursued in the following fields of specialization.

Biochemistry. — the study of enzyme catalysis, and the chemical properties of proteins, carbohydrates, complex lipids, nucleic acids, and protein-nucleic acid complexes. Methods of analysis include gene cloning, the use of genetic variants, synthetic substrates, and transition state analogs. Specific areas of study include the chemistry of oncogenes, the mechanism of RNA splicing, analysis of cytoskeletal proteins, the chemistry of blood coagulation, the mechanism of ion pumps and photoreceptors, and the role of complex carbohydrates in cell surface function and protein compartmentalization.

Genetics/Microbiology. — genetic analyses of fundamental problems in bacteria bacteriophage, viruses, and yeast. Areas of specific interest include protein secretion, DNA transposition, protein turnover, DNA synthesis and repair, mechanisms of genetic recombination, and electron transport in mitochondria. More complex problems under study are cellular responses to stress, plant-bacterial interactions, high-resolution structure-function studies of proteins and tRNAs, and the control circuits regulating gene expression. A new area of study is the application of high-resolution molecular techniques to problems in human genetics.

Cell Biology. — molecular biological, genetic, and cell biological analysis of eukaryotic cells. The specific areas of research include the organization, expression, and regulation of eukaryotic genomes; the structure and function of membranes and cytoskeletons; the molecular basis of cellular structure, organization, proliferation, and movement; the differentiation and functions of specialized cell types; and the molecular basis of various diseases.

Biophysical Chemistry and Molecular Structure. — studies of the principles that underlie the folding, stability, molecular design, and assembly of proteins and nucleic acids. Analysis of molecular structure by X-ray crystallography and NMR. Specific areas of concentration include the study of genetic strategies for enhancing the stability, ligand affinity, and catalytic efficiency of proteins and enzymes; pathways of protein folding; protein-nucleic acid recognition; and antigen-antibody interactions. Studies of more complex systems include the control of viral and cytoskeletal assembly.

Developmental Biology — the cellular, genetic, and molecular mechanisms responsible for 1) generating the diversity of cell types that arise during development and 2) controlling the ways in which cells interact to produce organ systems and whole organisms. These problems are studied using vertebrates (birds, amphibians, mammals), invertebrates (nematodes, sea urchins, fruit flies) and plants *(Arabadopsis).* Specific topics of interest include the regulation of gene expression, cell interactions, cell lineages, cell migrations, and the mechanism of sex determination.

Immunology — the study of the genetic, cellular, and molecular mechanisms underlying the exquisite sensitivity and specificity of the immune system. The immunology group studies the chemistry of antigen-antibody and antigen-T cell receptor interactions, using the tools of molecular biology as well as classical immunological approaches. Of particular interest is the role of idiotypic and cellular interactions in the regulation of the immune system as studied by organ culture, hybridoma technology, and the behavior of transgenic mice.

Neurobiology. Neurobiology is an area of recent emphasis in the Department. We currently offer a course in general neurobiology, supplemented by a seminar series and an inter-laboratory journal club. The emphasis here is molecular, primarily using cell-biological, developmental, and genetic approaches. Present areas of research interest include the molecular determinants of neuronal diversity and shape; of cell-adhesive, cell-inductive, and synaptic interactions; and the genetic and molecular determinants of cell-lineages, memory storage, and sensory transduction.

Entrance Requirements for Graduate Study

In the Department of Biology, the Master of Science is not a prerequisite for a program of study leading to the doctorate.

The Department modifies the General Institute Requirements for admission to graduate study as follows: 18.01, 18.02 Calculus; one year of college physics; 5.12 Organic Chemistry I; professional subjects including general biochemistry, genetics, and physical chemistry. Deficiencies in any of these subjects may be removed while enrolled in a graduate program.

Doctor of Philosophy

The General Institute Requirements for the Doctor of Philosophy are listed in Chapter IV on Graduate Education. In the Departmental program, each graduate student is expected to acquire a solid background in four fundamental areas of biology: biochemistry, genetics, cell biology, and molecular biology. Most students take courses in these areas during the first year. All students are required to take three courses: Genetics, Biochemistry for Graduate Students, and Method and Logic in Molecular Biology. This last course is a seminar designed specifically to introduce graduate students to in-depth discussion and analysis of topics in molecular biology.

Students also have a choice of several elective courses, which have been designed for the entering graduate student. In addition to providing a strong formal background in biology, the first-year program serves to familiarize the students with faculty and students in all parts of the department.

Joint MIT-Woods Hole Oceanographic Institution Program Course VII-W

Biological Oceanography. MIT and WHOI administer a joint program in biological oceanography leading to a jointly awarded Doctor of Philosophy. For details of this program, see Joint Program in Oceanography and Oceanographic Institution, at the end of this chapter.

Financial Support

Students who are accepted into the graduate program are generally provided with support from departmental training grants, departmental funds for teaching assistants, and research grants. In addition, some students bring NSF and other competitive fellowships. Through these sources, full tuition plus a stipend for living expenses are provided.

Students are encouraged to apply for outside fellowships for which they are eligible, such as the National Science Foundation Fellowships. Information regarding graduate student fellowships is available at most colleges from the career planning office.

Inquiries

Additional information regarding graduate academic programs, research activities, admissions, financial aid, and assistantships may be obtained from Biology Headquarters, Graduate Administrator, Room 56-524, MIT, Cambridge, Massachusetts 02139, (617) 253-4738.

Department of Chemistry

Mark Stephen Wrighton, Ph.D.
Frederick G. Keyes Professor of Chemistry
Head of the Department

Professors

Robert Arnold Alberty, Ph.D., Sc.D.
Professor of Chemistry

Glenn Allen Berchtold, Ph.D.
Professor of Chemistry

Klaus Biemann, Ph.D.
Professor of Chemistry

George Hermann Büchi, D.Sc.
Camille Dreyfus Professor of Chemistry

Alan Davison, Ph.D.
Professor of Chemistry

John Mark Deutch, Ph.D., Sc.D.
Karl Taylor Compton Professor of Chemistry
Provost

Robert Warren Field, Ph.D.
Professor of Chemistry

Carl Wesley Garland, Ph.D.
Professor of Chemistry

Frederick Davis Greene II, Ph.D., Sc.D.
Professor of Chemistry

Daniel Schaeffer Kemp, Ph.D.
Professor of Chemistry

Har Gobind Khorana, Ph.D.
Alfred P. Sloan Professor of Biology and Chemistry

Alexander M. Klibanov, Ph.D.
Professor of Chemistry

Stephen James Lippard, Ph.D.
Professor of Chemistry

Satoru Masamune, Ph.D.
Professor of Chemistry

William Henry Orme-Johnson, Ph.D.
Professor of Chemistry

Irwin Oppenheim, Ph.D.
Professor of Chemistry

Gregory Anthony Petsko, D.Phil.
Professor of Chemistry

Richard Royce Schrock, Ph.D.
Professor of Chemistry

Dietmar Seyferth, Ph.D.
Robert T. Haslam and Bradley Dewey Professor of Chemistry

K. Barry Sharpless, Ph.D.
Arthur C. Cope Professor of Chemistry

Robert James Silbey, Ph.D.
Professor of Chemistry

Jeffrey Irwin Steinfeld, Ph.D.
Professor of Chemistry

JoAnne Stubbe, Ph.D.
Ellen Swallow Richards Professor of Chemistry

Steven Robert Tannenbaum, Sc.D.
Professor of Chemistry
Professor of Toxicology
Whitaker College

John Stewart Waugh, Ph.D.
Arthur Amos Noyes Professor of Chemistry

Gerald Norman Wogan, Ph.D.
Underwood-Prescott Professor of Chemistry
Professor and Director, Program in Toxicology, Whitaker College

Associate Professors

Sylvia Teresse Ceyer, Ph.D.
Associate Professor of Chemistry

Rick Lane Danheiser, Ph.D.
Associate Professor of Chemistry

John Martin Essigmann, Ph.D.
Associate Professor of Chemistry and Associate Professor of Toxicology, Whitaker College

Keith Adam Nelson, Ph.D.
Associate Professor of Chemistry

Assistant Professors

Stephen Leffler Buchwald, Ph.D.
Assistant Professor of Chemistry

Peter Thomas Lansbury, Jr., Ph.D.
Assistant Professor of Chemistry

Philip Wirth Phillips, Ph.D.
Assistant Professor of Chemistry

Douglas C. Youvan, Ph.D.
Atlantic Richfield Assistant Professor of Chemistry

Lecturer

Dagmar Ringe, Ph.D.

Senior Research Scientist

Catherine Elizabeth Costello, Ph.D.

Principal Research Scientist

William M. Davis, Ph.D.

Technical Instructor

James Alexander Simms

Administrative Officer

Marc Bennett Jones, B.A.

Financial Administrator

Joan Marie Hutchins

Personnel Administrator

Anne Marie Lees

Professors Emeriti

Edmund Lee Gamble, Ph.D.
Professor of Inorganic Chemistry, Emeritus

David Newton Hume, Ph.D.
Professor of Analytical Chemistry, Emeritus

John Withers Irvine, Jr., Ph.D., Sc.D.
Professor of Chemistry, Emeritus

Richard Collins Lord, Ph.D., Sc.D.
Professor of Chemistry, Emeritus
Senior Lecturer

John Clark Sheehan, Ph.D., Sc.D.
Professor of Organic Chemistry, Emeritus

Clark Conkling Stephenson, Ph.D.
Professor of Chemistry, Emeritus
Senior Lecturer

Department of Chemistry

(Course 5)

Undergraduate Study

Bachelor of Science in Chemistry Course V

The Department offers an undergraduate program sufficiently flexible in its electives to provide excellent preparation for careers in many different areas of chemistry. The Course is designed to provide an education based on science both for those who intend to go on to graduate study and for those who intend to immediately pursue professional careers in either chemistry or an allied field in which a sound knowledge of chemistry is important. Students receive thorough instruction in the principles of chemistry, supplemented by a firm foundation in mathematics, physics, the humanities, and other subjects. The Departmental Program is accredited by the American Chemical Society.

Unrestricted elective time allows students to extend their knowledge in areas of special interest. Those intending to do graduate work may elect subjects in the Department or in other departments that give them more detailed knowledge in the areas in which they wish to specialize. Students who plan to enter industry may elect subjects that offer the fundamentals in a selected field of science, engineering, or the humanities and social sciences. Five-year programs may also be elected that lead to simultaneous Bachelor of Science degrees in two fields of specialization.

The student's faculty advisor can offer suggestions for elective subjects that are of value in preparation for specialization in the various broad areas of chemistry. The proper choice of electives is particularly important for students planning to continue their education in a graduate school.

Course V also aims to develop a strong grounding in research principles and experience, and the curriculum may include a research project giving students opportunities to demonstrate aptitude for creative efforts.

Inquiries

Additional information may be obtained from the Chemistry Department, Undergraduate Office, Room 2-325, MIT, Cambridge, Massachusetts 02139, (617) 253-7271.

Bachelor of Science in Chemistry Course V

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [1 subject can be satisfied by 5.12 or 5.60 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 5.311 in the Departmental Program]	1
TOTAL Subjects	17

PLUS

Departmental Program	Units

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects:		120
5.03	Principles of Inorganic Chemistry I, 12; 5.12	
5.11	Principles of Chemical Science[1], 12	
5.12	Organic Chemistry I, 12; 5.11	
5.13	Organic Chemistry II, 12; 5.11, 5.12	
5.311	Introductory Chemical Experimentation, 12; 5.12	
5.32	Intermediate Chemical Experimentation, 15; 5.311**, *5.13, 5.60*	
5.33	Advanced Chemical Instrumentation, 21; 5.32, *5.61*	
5.60	Chemical Thermodynamics[1], 12; *18.02*	
5.61	Physical Chemistry, 12; 8.02, 18.02	
Restricted Electives:		**24**
At least two of the following three subjects:		
5.04	Principles of Inorganic Chemistry II, 12; 5.03	
5.43	Organic Chemistry, 12; 5.13	
5.62	Physical Chemistry, 12; 5.60**	
Units in Departmental Program that also satisfy the General Institute Requirements		**(24)**
Unrestricted Electives[1]		**60**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements		**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

1
Students who take 5.11 to fulfill the General Institute Requirement in Chemistry must take 12 additional units of Unrestricted Electives.

Bachelor of Science in Chemistry Course V

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement[1]	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 5.11 or 5.12 or 5.60 in the Departmental Program, plus appropriate subjects totaling	24
Laboratory Requirement can be satisfied by 5.311 in the Departmental Program.	

Departmental Program	

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects:		120
5.03	Principles of Inorganic Chemistry I, 12; 5.12	
5.11	Principles of Chemical Science[1], 12	
5.12	Organic Chemistry I, 12; 5.11	
5.13	Organic Chemistry II, 12; 5.11, 5.12	
5.311	Introductory Chemical Experimentation, 12; 5.12	
5.32	Intermediate Chemical Experimentation, 15; 5.311*, *5.13, 5.60*	
5.33	Advanced Chemical Instrumentation, 21; 5.32, *5.61*	
5.60	Chemical Thermodynamics[1], 12; *18.02*	
5.61	Physical Chemistry, 12; 8.02, 18.02	
Restricted Electives:		**24**
At least two of the following three subjects:		
5.04	Principles of Inorganic Chemistry II, 12; 5.03	
5.43	Organic Chemistry, 12; 5.13	
5.62	Physical Chemistry, 12; 5.60*	
Unrestricted Electives[1]		**60**
Total Units Required for the S.B. Degree		**360**

*Alternate prerequisites are listed in the subject description.

1
Students who take 5.11 to fulfill the General Institute Requirement in Chemistry must take 12 additional units of Unrestricted Elective.

Graduate Study

The Department of Chemistry offers the Master of Science in Chemistry, the Doctor of Philosophy, and the Doctor of Science. The subjects offered for these degrees aim to develop a sound knowledge of fundamentals and a familiarity with current progress in the most active and important areas of chemistry. In addition to studying formal subjects, each student undertakes a research problem that forms the core of graduate work. Through the experience of conducting an investigation leading to the master's or doctoral thesis, a student learns general methods of approach and acquires training in some of the specialized techniques of research.

The areas of research in the Department are organic, inorganic, physical, biological, and biophysical chemistry; biochemistry; and chemical physics. The thesis frequently involves more than one of these fields. Some of the research activities of the Department are carried out in association with the work of various interdisciplinary laboratories and centers such as the Center for Materials Science and Engineering, the Research Laboratory of Electronics, and the Spectroscopy Laboratory, described in Chapter VI. These interdepartmental research laboratories provide stimulating interaction among the research programs of several MIT departments and give students the opportunity to become familiar with research work in disciplines other than chemistry. There also is an opportunity for research in cooperation with other departments such as Biology; Earth, Atmospheric, and Planetary Sciences; and Physics. Detailed information on the research activities of the faculty can be found in the *Directory of Graduate Research* published by the American Chemical Society.

During the first term of residence, all graduate students are encouraged to select research supervisors who serve as advisors for the balance of their graduate careers. In particular, the overall program of graduate subjects to be taken is established by each student and the research supervisor. In planning this program and in establishing the thesis problem, careful consideration is given to the candidate's academic record and professional experience, as well as to long-range objectives.

Entrance Requirements for Graduate Study

Students intending to pursue graduate work in the Department should have excellent undergraduate preparation in chemistry. The Department, however, is flexible with respect to the specific mathematics and physics preparation; the essential requirement is demonstration of ability to progress with advanced study and research in some area of special interest. Mathematics and physics are important prerequisites for graduate work in physical chemistry or chemical physics, whereas less preparation in these areas is required for work in organic chemistry.

Applicants for financial assistance from the Department of Chemistry are requested to submit scores from the Verbal and Quantitative sections of the Graduate Record Examination. Scores on the Advanced examinations are optional.

Although doctoral studies are the principal focus of the graduate program in the Department of Chemistry, applications are also accepted from students who do not wish to go beyond the Master's degree. Applicants whose ultimate goal is the Ph.D. or Sc.D. should apply to the Department as doctoral students, since the Master's degree is not a prerequisite for the Ph.D. or Sc.D. in Chemistry at MIT.

Master of Science in Chemistry

The general requirements for the Master of Science are listed in Chapter IV.

Doctor of Philosophy and Doctor of Science

The Department does not have any formal subject requirements for the doctoral degree. Each student, with advice of a research supervisor, pursues an individual program of study that is pertinent to long-range research interests.

Written major examinations are cumulative. Separate examinations in biological, inorganic, organic, and physical chemistry are offered each month during October through May. The examinations demonstrate an understanding of the important principles of each field, and most of the examinations are based on recent seminars and current literature. Six cumulative examinations must be passed to complete the written major examination. No fixed time limit is set for completion of this requirement; however, progress is reviewed periodically. No other general written examinations are required. In particular, no qualifying (or "entrance") examinations are given.

A comprehensive oral examination in the candidate's major field of advanced study is held near the end of the third term of residence. Progress in the student's research is also examined at that time. A final oral presentation on the subject of the doctoral research is scheduled after the thesis has been submitted and tentatively evaluated by a committee of examiners.

Teaching and Research Assistantships

The Department appoints a number of degree candidates as teaching assistants who are usually assigned to laboratory subjects or to discussion sections of lecture subjects. Many students receive appointments to research assistantships after their first year, and Departmental fellowships also are available. Financial support after the first academic year is provided for students who maintain a satisfactory record, subject to the availability of funds.

Inquiries

Correspondence about the graduate program or appointments should be addressed to the Chairman of the Departmental Committee on Graduate Students, Professor G. A. Berchtold, Chemistry Graduate Office, Room 18-392, MIT, Cambridge, Massachusetts 02139, (617) 253-1845.

Department of Earth, Atmospheric, and Planetary Sciences

Thomas Hillman Jordan, Ph.D.
Robert R. Shrock Professor of Earth and Planetary Sciences
Head of the Department

Professors

William Francis Brace, Ph.D.
Cecil and Ida Green Professor of Geology

Burrell Clark Burchfiel, Ph.D.
Schlumberger Professor of Geology

Roger George Burns, Ph.D.
Professor of Geochemistry

Charles Claude Counselman III, Ph.D.
Professor of Planetary Sciences

John Marmion Edmond, Ph.D.
Professor of Oceanography

James Ludlow Elliot, Ph.D.
Professor of Astronomy and Physics
Director, George R. Wallace, Jr., Astrophysical Observatory

Kerry Andrew Emanuel, Ph.D.
Professor of Meteorology

Glenn Richard Flierl, Ph.D.
Professor of Oceanography

Frederick August Frey, Ph.D.
Professor of Geochemistry

Stanley Robert Hart, Ph.D.
Professor of Geology and Geochemistry

Richard Siegmund Lindzen, Ph.D.
Alfred P. Sloan Professor of Meteorology

Theodore Richard Madden, Ph.D.
Professor of Geophysics

Reginald Edward Newell, Sc.D.
Professor of Meteorology

Gordon Hemenway Pettengill, Ph.D.
Professor of Planetary Physics
Director, Center for Space Research

Raymond Alan Plumb, Ph.D.
Professor of Meteorology

Ronald George Prinn, Sc.D.
Professor of Meteorology

M. Gene Simmons, Ph.D.
Professor of Geophysics

Sean Carl Solomon, Ph.D.
Professor of Geophysics

John Brelsford Southard, Ph.D.
Professor of Geology

Peter Hunter Stone, Ph.D.
Professor of Meteorology
Director, Center for Meteorology and Physical Oceanography

M. Nafi Toksöz, Ph.D.
Professor of Geophysics
Director, Earth Resources Laboratory
Director, George R. Wallace, Jr., Geophysical Observatory

Carl Isaac Wunsch, Ph.D.
Cecil and Ida Green Professor of Physical Oceanography
Secretary of the Navy Research Professor

Associate Professors

Edward Allen Boyle, Ph.D.
Associate Professor of Chemical Oceanography

J. Brian Evans, Ph.D.
Associate Professor of Geophysics

Timothy L. Grove, Ph.D.
Associate Professor of Petrology

Kip V. Hodges, Ph.D.
Associate Professor of Geology

Marcia K. McNutt, Ph.D.
Associate Professor of Marine Geophysics

Paola Malanotte Rizzoli, Ph.D.
Associate Professor of Oceanography

Leigh H. Royden, Ph.D.
Associate Professor of Geology and Geophysics

Assistant Professors

Richard P. Binzel, Ph.D.
Assistant Professor of Planetary Science

Randall M. Dole, Ph.D.
Assistant Professor of Meteorology

John P. Grotzinger, Ph.D.
Assistant Professor of Geology

David C. Jewitt, Ph.D.
Assistant Professor of Planetary Science

Jason Phipps Morgan, Ph.D.
Assistant Professor of Geophysics

Daniel H. Rothman, Ph.D.
Assistant Professor of Geophysics

Earle R. Williams, Ph.D.
Assistant Professor of Meteorology

Jack Wisdom, Ph.D.
Assistant Professor of Planetary Science

Visiting Professor

Claude J. Frankignoul, Ph.D.
Professor of Oceanography

Senior Lecturers

John Carl Foster, Ph.D.
Richard D. Rosen, Ph.D.
Joseph E. Salah, Ph.D.

Lecturer

John M. Holt, Ph.D.

Honorary Lecturer

Cecil H. Green, S.M., D.S.C., LL.D.

Administrative Officer

Susan Guralnik, B.A., M.A.

Administrative Staff

Harriet Kounaves, B.A., M.A.
Donna Martel
Carol Ann Ramey

Senior Research Scientists

Peter Molnar, Ph.D.

Nobumichi Shimizu, D.Sc.
Director, Ion Probe Facility

Principal Research Scientists

Chuen Hon Cheng, Sc.D.
Edward Dunham, Ph.D.
M. Bruce Fegley, Ph.D.
Robert W. King, Jr., Ph.D.
Christopher I. Measures, Ph.D.

Research Associates

Richard Abbott, Ph.D.
Eric Bergman, Ph.D.
Yehuda Bock, Ph.D.
Teresa Bowers, Ph.D.
Andrew Campbell, Ph.D.
Peter Ford, Ph.D.
Sergei Gourevitch, Ph.D.
Levent Gulen, Ph.D.
Gary Klinkhammer, Ph.D.
Ralph Markson, Ph.D.
Robert McCaffrey, Ph.D.
Stephen Meacham, Ph.D.
Steven Recca, M.S.
Alexander Rechester, Ph.D.
Robert Reilinger, Ph.D.
Roger Turpening, Ph.D.
Jane Hsiung Wojcik, Ph.D.
Roberta Young, Ph.D.

Research Engineers

Kenneth Burrhus
Walter Cook, M.S.
Spiros Geotis
George Keough

Research Specialists

Timothy Barash, B.A.
Carol Blackway Caravana, M.S.
Barbara Grant, M.S.
Pillalmarri Ila, Ph.D.
Mitra Khadem, B.S.
Charmaine King, B.S.
David Krowitz, B.S.
Jane Maloof, B.S.
Linda Meinke, B.S.
Paula Rosener, B.A.
Diana Spiegel, M.S.

Research Staff, Administrative

Sara H. Brydges, B.S.
Jane S. McNabb, B.A.
Albert L. Taylor

Postdoctoral Associates

Norman Barth, Ph.D.
Yves Bernabe, Ph.D.
Wafik Beydoun, Ph.D.
Jerzy Blusztajn, Ph.D.
Philippe Gaspar, Ph.D.
Dong-Shan Ko, Ph.D.
Kristin Orians, Ph.D.
Martin Palmer, Ph.D.
Douglas Toomey, Ph.D.

Department of Earth, Atmospheric, and Planetary Sciences

(Course 12)

Undergraduate Study

Visiting Scientists

Bruce Anderson, Ph.D.
Abdullatif Barka, Ph.D.
Anton Dainty, Ph.D.
Danan Dong, M.S.
Amram Golombek, Ph.D.
Fatih Güler, M.S.
Katherine Kadinsky-Cade, Ph.D.
Xianlang Li, B.S.
Hans-Rainier Schneider, Ph.D.

Research Affiliates

Norman Gaut, Ph.D.
Robert Heinmiller, Ph.D.
Robert Kraichnan, Ph.D.

Professors Emeriti

James Murdoch Austin, Sc.D.
Professor of Meteorology, Emeritus

Harold Williams Fairbairn, Ph.D.
Professor of Geology, Emeritus

Patrick Mason Hurley, Ph.D.
Professor of Geology, Emeritus

Edward Norton Lorenz, Sc.D.
Professor of Meteorology, Emeritus

William F. Pinson, Jr., Ph.D.
Associate Professor of Geology, Emeritus

Frederick A. Sanders, Ph.D.
Professor of Meteorology, Emeritus

Robert Rakes Shrock, Ph.D.
Professor of Geology, Emeritus

Hurd Curtis Willett, Ph.D.
Professor of Meteorology, Emeritus

The Department of Earth, Atmospheric, and Planetary Sciences offers the bachelor's degree in earth, atmospheric, and planetary sciences, and the master's and doctoral degrees in earth and planetary sciences, in meteorology, and in oceanography.

Observations of the sky, sea, surface, and the planet's interior inspire ingenious syntheses of physics, chemistry, and mathematics. Department programs employ the basic sciences to understand the origins, evolution, composition, and structure of the earth and other planets, and to explain phenomena as diverse as the motions of continents, asteroids, and weather systems.

Department faculty members teach and conduct research in a broad range of subjects, including mineralogy-crystallography, sedimentology, petrology, rock mechanics, geochemistry, chemical oceanography, geochronology, tectonics, geodesy, seismology, geomagnetism and geoelectricity, heat flow, high-pressure geophysics, geophysical fluid dynamics, observational and dynamical meteorology, atmospheric electricity, physical oceanography, marine geology and geophysics, optical and radar astronomy, dynamical astronomy, comets and meteors, planetary rings, and planetary atmospheres.

Modern problems in these fields are approached by field measurements, laboratory studies, and theory. Experimental facilities for training and research are available not only in departmental laboratories such as the Earth Resources Laboratory, but also in MIT's interdepartmental laboratories such as the Center for Space Research, the Lincoln Laboratory, the Haystack Radio Observatory and Millstone Radar facility, and the Wallace Astrophysical and Geophysical observatories (described in Chapter VI), and in cooperating institutions such as the Woods Hole Oceanographic Institution.

Graduate programs in meteorology and physical oceanography are provided through the Center for Meteorology and Physical Oceanography. The programs in these areas draw upon physics, mathematics, and chemistry but emphasize fluid dynamics. The solutions to many environmental problems will depend upon increased knowledge of the earth's atmosphere and oceans. The Center's graduate programs are designed to provide students with a broad background in these areas. The research programs of the Center are described later in this section. The program in physical oceanography is offered jointly with the Woods Hole Oceanographic Institution.

Students are encouraged to take advantage of the offerings in the Undergraduate Seminar Program and the Undergraduate Research Opportunities Program to become involved in the fields of earth and planetary sciences, meteorology, and oceanography.

Bachelor of Science in Earth, Atmospheric, and Planetary Sciences
Course XII

The Department offers undergraduate preparation for professional careers in the earth, atmospheric, and planetary sciences. Some students concentrate in specific fields in these areas. Others choose to combine basic studies in mathematics, physics, chemistry, or engineering with applications to earth, atmospheric, and planetary sciences.

The curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences contains only a minimum number of specific requirements, to allow maximum flexibility in arranging an individualized program of study. Lists of undergraduate research and employment opportunities are available from the Department.

Students are encouraged to enter the Department of Earth, Atmospheric, and Planetary Sciences at the beginning of their second year to obtain the maximum benefit from advisor resources; however, interested students are encouraged to visit Department headquarters at any time to arrange conferences with advisors.

Restricted Elective Requirements. Each student's program of restricted electives is individually arranged in consultation with the advisor. For guidance, sample programs in geology, geochemistry, geophysics, meteorology and physical oceanography, atmospheric and oceanic chemistry, planetary physics, and astronomy are available from the Department Headquarters, Room 54-913. A variety of other programs can be worked out in consultation with the student's advisor.

Some of the restricted electives in these programs, or any alternate programs submitted, can be selected in part to meet the particular needs and interests of individual students. Approval of these programs is based on their scope, depth, and relevance to sound preparation in earth, atmospheric, and planetary sciences. Programs normally should be submitted for approval by the middle of the student's third year.

Students who wish to defer choosing a field of concentration within Course XII can prepare for all of the options by completing 5.60 Chemical Thermodynamics, 8.03 Physics III, 12.02 Chemistry and Physics of Minerals and Rocks, and 18.03 Differential Equations during their second year.

Research Requirement. Each student is required to undertake a minimum of 12 units of research supervised in the Department. Many students take significantly more, and some petition the Committee on Curricula to have this research satisfy the Institute Laboratory Requirement as well. By petition to the Departmental Committee on Undergraduates, suitably planned and executed research or individual study also may be substituted for classroom subjects. Also by petition, students may satisfy the departmental research requirement by means of projects on which they have worked for pay rather than for credit, either within the department or elsewhere, provided that the student can demonstrate that the activity constitutes a substantial research experience.

Bachelor of Science in Earth, Atmospheric, and Planetary Sciences Course XII

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement[1]	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 18.03 and by 5.60 or 3.00 in the Departmental Program]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	60
One of the following two subjects:	
5.60 Chemical Thermodynamics[1], 12; *18.02*	
3.00 Thermodynamics of Materials, 12; 18.02	
plus	
8.03 Physics III, 12; 8.02**, 18.02	
or one of the following four subjects chosen in consultation with the advisor:	
1.60 Fluid Dynamics, 12; 18.03	
3.11 Mechanics of Materials, 12; 8.01, 18.02	
5.61 Physical Chemistry, 12; 8.02, 18.02	
18.354 Fluid Mechanics, 12; 18.04**	
One of the following three subjects:	
12.091 Special Problems (at least 12 units)	
12.ThU Undergraduate Thesis (at least 12 units)	
12.UR Undergraduate Research (at least 12 units)	
One of the following four subjects:	
12.07 Chemistry and Physics of the Earth, 12; 8.02, 18.03	
12.131J Planetary Science I, 12; 8.03, 18.03	
12.21 Physics of the Ocean, 12; 8.03, 18.03	
12.811 Introduction to Meteorology, 12; 8.03, 18.03	
plus	
18.03 Differential Equations, 12; 18.02**	
Restricted Electives:	84
A coherent program of electives selected in consultation with the faculty advisor and approved by the Departmental Committee on Undergraduates (see text)	
Units in Departmental Program that also satisfy the General Institute Requirements	(24)
Unrestricted Electives	60
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Double-Degree Programs/Five-Year Programs

Studies in physics, chemistry, biology, applied mathematics, and electrical or civil engineering are directly relevant preparation for work in earth, atmospheric, and planetary sciences. Students from these departments can arrange flexible programs of study in Course XII leading to a second Bachelor of Science in one of these areas.

Students with strong academic records from the Departments of Chemistry; Electrical Engineering and Computer Science; Physics; Earth, Atmospheric, and Planetary Sciences; or Mathematics should be able to complete a Master of Science in Earth and Planetary Sciences in meteorology and physical oceanography in one year of additional study, particularly if programs are arranged for this purpose from the beginning of the fourth year. Applications for graduate enrollment in the Department are considered any time after the beginning of the fourth year. Students may receive the Bachelor of Science as soon as the requirements are completed, or may elect to defer the award for simultaneous presentation with the Master of Science.

Inquiries

Additional information may be obtained from the Department of Earth, Atmospheric, and Planetary Sciences, Department Headquarters, Room 54-913, MIT, Cambridge, Massachusetts 02139, (617) 253-3381. Specific information and advice with respect to studies in meteorology may be obtained from Professor Peter H. Stone, Room 54-1712, (617) 253-2281.

1 Students who have taken 5.60 to fulfill the General Institute Requirement in Chemistry must take 12 additional units of Science Distribution subjects.

Graduate Study

Bachelor of Science in Earth, Atmospheric, and Planetary Sciences Course XII

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement[1]		60
Humanities, Arts, and Social Sciences Requirement		72
Science Distribution Requirement can be satisfied by 18.03, by 5.60 or 3.00, and by 8.03, 3.11, or 5.61 in the Departmental Program[1]		
Laboratory Requirement		12
Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		60
One of the following two subjects:		
5.60	Chemical Thermodynamics[1], 12; *18.02*	
3.00	Thermodynamics of Materials, 12; 18.02	
	plus	
8.03	Physics III, 12; 8.02*, 18.02	
or one of the following four subjects chosen in consultation with the advisor:		
1.60	Fluid Dynamics, 12; 18.03	
3.11	Mechanics of Materials, 12; 8.01, 18.02	
5.61	Physical Chemistry, 12; 8.02, 18.02	
18.354	Fluid Mechanics, 12; 18.04*	
One of the following three subjects:		
12.091	Special Problems (at least 12 units)	
12.ThU	Undergraduate Thesis (at least 12 units)	
12.UR	Undergraduate Research (at least 12 units)	
One of the following four subjects:		
12.07	Chemistry and Physics of the Earth, 12; 8.02, 18.03	
12.131J	Planetary Science I, 12; 8.03, 18.03	
12.21	Physics of the Ocean, 12; 8.03, 18.03	
12.811	Introduction to Meteorology, 12; 8.03, 18.03	
	plus	
18.03	Differential Equations, 12; 18.02*	
Restricted Electives:		84
A coherent program of electives selected in consultation with the faculty advisor and approved by the Departmental Committee on Undergraduates (see text)		
Unrestricted Electives		72
Total Units Required for the S.B. Degree		360

***Alternate prerequisites are listed in the subject description.**

1
Students who have taken 5.60 to fulfill the General Institute Requirement in Chemistry must take 12 additional units of Science Distribution subjects.

The Department of Earth, Atmospheric, and Planetary Sciences offers opportunities for graduate study and research in a wide range of fields, as indicated by the detailed subject descriptions in Chapter VIII. This coursework is the usual prelude to a thesis demonstrating that the student is capable of independent and creative research. A successful thesis leads to a graduate degree, either a Master of Science, a Doctor of Philosophy or a Doctor of Science in the field of specialization.

A graduate thesis may have either a theoretical, experimental, or observational focus. Modern laboratory facilities, computers, instrumentation, and extensive collections of specimens and data are available to students. Field study is an essential part of the graduate curriculum in geology, geophysics, and geochemistry, and special arrangements may be made for summer employment and field research on Departmental projects and with industrial organizations and government agencies. In oceanography, sea-going observational research is an important part of the educational experience. In meteorology and oceanography, graduate study includes a mixture of theoretical and experimental studies sharing a common appreciation of the dynamics of the underlying process.

Entrance Requirements for Graduate Study

In addition to the General Institute Requirements for admission, as found in Chapter IV, the Department requires preparation equivalent to the curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences at MIT for graduate studies in that field. For meteorology and oceanography, the most essential element is a sound preparation in mathematics and physics, supplemented if possible by some chemistry. Students taking their undergraduate work at other institutions are advised to include in their programs the equivalent of the mathematics and physics contained in the MIT undergraduate curricula. If students are not fully prepared in certain of the fields or required subjects, they usually are asked to extend their studies in these areas while pursuing advanced work. The doctoral program can be entered without a Master of Science as a prerequisite.

Joint MIT-Woods Hole Oceanographic Institution Program in Oceanography and Oceanographic Engineering

MIT and WHOI have established a program in oceanography which leads to a jointly awarded degree of the Doctor of Philosophy or the Doctor of Science. For details of this program, see Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution, at the end of this chapter.

Master of Science in Earth and Planetary Sciences, in Meteorology, or in Oceanography

The General Institute Requirements for the degree of Master of Science in Earth and Planetary Science, in Meteorology, or in Oceanography are described in Chapter IV. An individual program of study and research is arranged to suit the special background, needs, and goals of each student. The program is worked out in detail by the student with his or her personal faculty advisor and a Departmental committee. There are no foreign language requirements for the degree. Master's students in oceanography and meteorology have access to the facilities of the Joint MIT-WHOI Program.

Doctor of Philosophy and Doctor of Science

General Institute Requirements for the degree of Doctor of Philosophy or Doctor of Science are given in Chapter IV. The Department does not require candidates for the doctorate to present evidence of competence in a foreign language, but it strongly urges that candidates for the doctorate acquire intermediate competence in one or more languages. A specialized program of study and research is tailored to each student's background, needs, and goals by the student in consultation with a personal faculty advisor and a Departmental committee. A doctoral candidate's program is expected to be broad and to include formal study in other departments in addition to the specialized subjects that prepare the candidate for thesis research. Thesis research normally is begun immediately after successful completion of the general examination, by the end of the second year. The general examination is intended to test the candidate's aptitude and preparation for independent research.

Thesis research is closely supervised by one or more faculty members who are interested and knowledgeable in the research topic, who are chosen by the student, and who may be members of other departments. The thesis is expected to meet high professional standards, and to be a significant original contribution to the scientific field.

Teaching and Research Assistantships

The Department and the Center for Meteorology and Physical Oceanography offer a considerable number of research and teaching assistantships each year. Research assistants work on one of the many research projects in the Department or Center, which often is related to the student's thesis research. Teaching assistants assist in laboratory instruction or in the preparation of teaching materials and the grading of papers.

The Center also offers the Jule G. Charney Awards for graduate study. These awards are available to a few students to supplement the normal support from research assistantships or other fellowships. Selection of individuals is based on the excellence of the applicant's record, as evidenced by academic performance, letters of recommendation, professional accomplishments, and other awards such as National Science Foundation Fellowships.

Inquiries

Additional information regarding academic and current research programs in the Department, admission requirements, assistantship appointments, and financial aid may be obtained by writing to the Department of Earth, Atmospheric, and Planetary Sciences, Department Headquarters, Room 54-913, MIT, Cambridge, Massachusetts 02139, (617) 253-3381.

Center for Meteorology and Physical Oceanography

Meteorology

Formal subjects of instruction are offered in most principal areas of meteorology, supplemented by reading courses in a student's special area of interest. The subjects are described in Chapter VIII.

The Center's research and educational activities include all the principal areas of meteorology: atmospheric dynamics, synoptic meteorology, weather forecasting, radar meteorology, mesoscale meteorology, cloud physics, atmospheric electricity, atmospheric chemistry, climate dynamics, satellite meteorology, planetary atmospheres, air-sea interactions, observational meteorology, hydrometeorology, and air pollution. The Center maintains a Doppler weather radar system and a synoptic laboratory that receives and archives current weather data from the National Meteorological Center. The Center also has a computer facility with a medium-sized computer and peripheral equipment, and remote terminals enabling students and staff to communicate with large computers at the National Center for Atmospheric Research, NASA's Goddard Space Flight Center, and MIT's Information Services. The facility can be used for data analysis, plotting, satellite image processing, numerical modeling, and other applications. Some of the Center's staff have joint appointments at MIT's Haystack Observatory in Westford, Massachusetts. The Observatory's Millstone Hill radar systems are used in studies of the physics and dynamics of both the upper and lower atmospheres.

Cambridge and its surroundings contain a number of institutions active in meteorological research, which, in addition to private commercial firms, include Harvard University, Woods Hole Oceanographic Institution, the Air Force Geophysics Laboratory, and the Boston Office of the National Weather Service. Contact with the personnel of these institutions is maintained through seminars and symposia.

Oceanography

The Center for Meteorology and Physical Oceanography is active in physical oceanography research; faculty and students are currently engaged in theoretical studies of the oceanic circulation, observational studies at sea, laboratory models, and investigations of the interactions between the atmosphere and the ocean. The programs of graduate students in oceanography also include subjects in oceanography and related areas offered by several other MIT departments and the Woods Hole Oceanographic Institution.

Earth Resources Laboratory

The Earth Resources Laboratory (ERL) brings together faculty, staff, and students dedicated to research that will further our understanding of the earth and its resources. Intensive and multidisciplinary approaches are combined to investigate the problems of exploration and development of petroleum and other resources. Seismology and physical properties of earth materials, among other geophysical studies, provide a common thread for research projects. The Laboratory personnel, which total about 50, include departmental faculty, visiting faculty, research scientists, graduate students, undergraduate students, and support staff.

The major research areas at ERL are seismic wave propagation and inversion in heterogeneous media, borehole geophysics, reflection seismology/tomography, seismicity/ tectonics, image processing, and expert system (AI) applications to geophysical problems. There are extensive computing facilities, as well as ultrasonics, tomography, and rock physics laboratories supporting the research areas. Field data collection activities include the Wallace Geophysical Observatory and New England Seismic Network, a 2km-deep dedicated research borehole, and cooperative studies with other MIT departments, industrial research groups, Woods Hole Oceanographic Institution, Ocean Drilling (ODP), and Continental Drilling (DOSECC) programs.

The research activities at ERL are supported in equal measure by industry, US government agencies, and Founding Membership grants. Further information about ERL can be obtained at the Department Headquarters (54-913), at ERL Headquarters (E34-462), or by calling the Director, Professor M. N. Toksöz at (617) 253-7852.

Department of Mathematics

Arthur Paul Mattuck, Ph.D.
Class of 1922 Professor
of Mathematics
Head of the Department

Richard Burt Melrose, Ph.D.
Professor of Mathematics
Chairman, Committee on Pure
Mathematics

Daniel J. Kleitman, Ph.D.
Professor of Applied Mathematics
Chairman, Committee on Applied
Mathematics

Professors

Nesmith Cornett Ankeny, Ph.D.
Professor of Mathematics

Michael Artin, Ph.D.
Professor of Mathematics

David John Benney, Ph.D.
Professor of Applied Mathematics

Hung Cheng, Ph.D.
Professor of Applied Mathematics

Richard Mansfield Dudley, Ph.D.
Professor of Mathematics
(On leave, spring)

Daniel Z. Freedman, Ph.D.
Professor of Applied Mathematics

Harvey Philip Greenspan, Ph.D.
Professor of Applied Mathematics

Victor William Guillemin, Ph.D.
Professor of Mathematics

Sigurdur Helgason, Ph.D.
Professor of Mathematics

Kenneth Myron Hoffman, Ph.D.
Professor of Mathematics

Peter J. Huber, Ph.D.
Professor of Applied Mathematics

David S. Jerison, Ph.D.
Professor of Mathematics

Victor Kac, Ph.D.
Professor of Mathematics

Daniel Marinus Kan, Ph.D.
Professor of Mathematics
(On leave, spring)

Steven Kleiman, Ph.D.
Professor of Mathematics

Bertram Kostant, Ph.D.
Professor of Mathematics

George Lusztig, Ph.D.
Professor of Mathematics
(On leave, fall)

Robert D. MacPherson, Ph.D.
Professor of Mathematics

Haynes R. Miller, Ph.D.
Professor of Mathematics

James Raymond Munkres, Ph.D.
Professor of Mathematics
(On leave, spring)

Franklin Paul Peterson, Ph.D.
Professor of Mathematics

Hartley Rogers, Jr., Ph.D.
Professor of Mathematics

Gian-Carlo Rota, Ph.D.
Professor of Applied Mathematics
and Philosophy
(On leave, spring)

Gerald Enoch Sacks, Ph.D.
Professor of Mathematical Logic
(On leave)

Irving Ezra Segal, Ph.D.
Professor of Mathematics

Isadore Manual Singer, Ph.D.
Institute Professor
Professor of Mathematics

Richard Peter Stanley, Ph.D.
Professor of Applied Mathematics

Harold Mead Stark, Ph.D.
Professor of Mathematics
(On leave, spring)

William Gilbert Strang, Ph.D.
Professor of Mathematics
(On leave, spring)

Daniel W. Stroock, Ph.D.
Professor of Mathematics

Alar Toomre, Ph.D.
Professor of Applied Mathematics

Michèle Françoise Vergne, Ph.D.
Professor of Mathematics
(On leave, fall)

David Alexander Vogan, Ph.D.
Professor of Mathematics

Associate Professors

David Jay Anick, Ph.D.
Associate Professor of Mathematics

Sy David Friedman, Ph.D.
Associate Professor of Mathematics

Frank Thomson Leighton, Ph.D.
Associate Professor of Applied
Mathematics

Rodolfo Reuben Rosales, Ph.D.
Associate Professor of Applied
Mathematics

Michael Sipser, Ph.D.
Associate Professor of Applied
Mathematics

Lloyd Nicholas Trefethen, Ph.D.
Associate Professor of Applied
Mathematics

Nicholas P. Warner, Ph.D.
Associate Professor of Applied
Mathematics

Assistant Professors

Baruch Awerbuch, Ph.D.
Assistant Professor of Applied
Mathematics

Luis Casian, Ph.D.
Assistant Professor of Mathematics
(On leave)

Mark D. Haiman, Ph.D.
Assistant Professor of Applied
Mathematics

Dan S. Henningson, Ph.D.
Assistant Professor of Applied
Mathematics

Ehud Hrushovsky, Ph.D.
Assistant Professor of Mathematics
(On leave, fall)

Ali Nadim, Ph.D.
Assistant Professor of Applied
Mathematics

C. Frederick Pearson, Ph.D.
Assistant Professor of Applied
Mathematics

Antonio Sanchez-Calle, Ph.D.
Assistant Professor of Mathematics

David B. Shmoys, Ph.D.
Assistant Professor of Applied
Mathematics

Stephane L. Zaleski, Ph.D.
Assistant Professor of Applied
Mathematics
(On leave)

Zhenfang Zhou, Ph.D.
Assistant Professor of Mathematics

Visiting Professors

Stella Ashford, Ph.D.
Associate Professor of Mathematics

Greta M. Ljung, Ph.D.
Associate Professor of Applied
Mathematics

Mendel Fygenson, Ph.D.
Assistant Professor of Applied
Mathematics

Egon Schulte, Ph.D.
Assistant Professor of Applied
Mathematics

Eva Tardos, Ph.D.
Assistant Professor of Applied
Mathematics

C. L. E. Moore Instructors

Jonathan Block, Ph.D.
Bennett Chow, Ph.D.
Matthew J. Dyer, Ph.D.
Enric Frau, Ph.D.
Masaki Hanamura, Ph.D.
Yakov Karpishpan, Ph.D.
Michael Laskowski, Ph.D.
Jian-Shu Li, Ph.D.
Gordana Matić, Ph.D.
Norihiko Minami, Ph.D.
Alan Nadel, Ph.D.
Jürgen Rathmann, Ph.D.
Gordan Savin, Ph.D.
Hart Smith, Ph.D.
Douglas L. Ulmer, Ph.D.
Dave Witte, Ph.D.
Miljenko Zabcic, Ph.D.

Instructors in Applied Mathematics

Peter Hajnal, Ph.D.
Paul Matthews, Ph.D.
Roy Meshulam, Ph.D.
Krzysztof Pilch, Ph.D.
Lorenzo Polvani, Ph.D.
Andrew Stuart, Ph.D.
Christian Wieczerlowski, Ph.D.

Administration

James Edward Dalton, A.S.A.
Administrative Officer

Marie-Therese Kouo, M.P.A.
Personnel Administrator

Joanne E. Murray, B.S.
Academic Administrator

Phyllis Ruby, A.B.
Graduate Administrator

Department of Mathematics

(Course 18)

Undergraduate Study

Professors Emeriti

Warren Ambrose, Ph.D.
Professor of Mathematics, Emeritus

Herman Chernoff, Ph.D.
Professor of Applied Mathematics, Emeritus

Francis Begnaud Hildebrand, Ph.D.
Professor of Mathematics, Emeritus

Louis Norberg Howard, Ph.D.
Professor of Applied Mathematics, Emeritus

Chia-Chiao Lin, Ph.D.
Institute Professor
Professor of Applied Mathematics, Emeritus

William Ted Martin, Ph.D.
Professor of Education and Mathematics, Emeritus

Richard Donald Schafer, Ph.D.
Professor of Mathematics, Emeritus

Claude Elwood Shannon, Ph.D.
Donner Professor of Science and Professor of Mathematics and Electrical Engineering, Emeritus

Dirk Jan Struik, Ph.D.
Professor of Mathematics, Emeritus

George Brinton Thomas, Jr., Ph.D.
Professor of Mathematics, Emeritus

George William Whitehead, Ph.D.
Professor of Mathematics, Emeritus

An undergraduate degree in mathematics provides an excellent basis for graduate work in mathematics or computer science, or for employment in such mathematics-related fields as systems analysis, operations research, or actuarial science.

Because the career objectives of undergraduate mathematics majors are so diverse, each undergraduate's program is individually arranged through collaboration between the student and his or her faculty advisor. In general, students are encouraged to explore the various branches of mathematics, both pure and applied.

Undergraduates wishing to work in small groups under the supervision of a faculty member may elect an upper-level mathematics seminar. This is normally done during the junior year or the first semester of the senior year. The experience gained from active participation in a seminar conducted by a research mathematician is particularly valuable for a student planning to pursue graduate work in some branch of mathematics or a related field.

There are three undergraduate programs that lead to the degree Bachelor of Science in Mathematics: a General Mathematics Option, an Applied Mathematics Option for those who wish to specialize in that aspect of mathematics, and a Theoretical Mathematics Option for those who expect to pursue graduate work in pure mathematics. A fourth undergraduate program leads to the degree Bachelor of Science in Mathematics with Computer Science; it is intended for students seriously interested in both mathematics and computer science.

The interaction that takes place in the classroom is an important component of the learning experience in mathematics. Therefore, in none of the programs is advanced standing credit accepted toward fulfillment of any part of the Departmental Requirements other than 18.03. It is accepted, however, as Unrestricted Elective.

Bachelor of Science in Mathematics
Course XVIII
General Mathematics Option

This option is the one followed by most students who major in mathematics. Besides the General Institute Requirements, the requirements consist of 18.03 Differential Equations and eight 12-unit subjects in Course 18 of essentially different content, including at least six advanced subjects (first decimal digit one or higher). This leaves available 84 units of unrestricted electives. The requirements are flexible in order to accommodate several categories of students:

1) those who wish to pursue programs that combine mathematics with a related field (such as physics, economics, or management), 2) those who wish to divide their time between theoretical and applied mathematics, and 3) those who wish to use mathematics as a general Institute major.

Applied mathematics is the mathematical study of general scientific concepts, principles, and phenomena that, because of their widespread occurrence and application, relate or unify various disciplines. The core of the program at MIT concerns the following principles and their mathematical formulations: propagation, equilibrium, stability, optimization, cybernetics, statistics, and random processes. The undergraduate program provides a general introduction to most areas of applied mathematics and to several specific areas for study in greater depth.

Sophomores interested in applied mathematics typically survey the field of applied mathematics by enrolling in both 18.310 and 18.311 Principles of Applied Mathematics. Subject 18.310, given only in the first term, is devoted to the discrete aspects of the subject and may be taken concurrently with 18.03. Subject 18.311, given only in the second term, is devoted to continuous aspects and makes considerable use of differential equations.

The subjects in Group I of the program correspond roughly to those areas of applied mathematics making heavy use of discrete mathematics, while Group II emphasizes those subjects dealing mainly with continuous processes. Naturally, there is a good deal of overlap; for example, such subjects as probability or numerical analysis have both discrete and continuous aspects. In general, students in the applied mathematics option are encouraged to acquire as good a background as possible in both types of applied mathematics.

For those who wish to emphasize particular areas within the applied mathematics curriculum, sample programs are available in the Undergraduate Mathematics Office for the following specialties: combinatorics, computer science, fluid dynamics, numerical analysis, statistics, and theoretical physics.

Bachelor of Science in Mathematics
Course XVIII
Applied Mathematics Option

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [1 subject can be satisfied by 18.03 in the Departmental Program]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	60
18.03 Differential Equations, 12; 18.02	
18.310 Principles of Applied Mathematics, 12; 18.02	
18.311 Principles of Applied Mathematics, 12; 18.03	
One of the following two subjects:	
18.04 Complex Variables with Applications, 12; 18.03	
18.284 Introduction to Functions of a Complex Variable, 12; 18.03	
One of the following two subjects:	
18.06 Linear Algebra, 12; 18.02	
18.421J Algorithmic Algebra and Number Theory, 12; 18.06**, 18.310**	
Restricted Electives:	48
Four additional Course 18 subjects from the following two groups with at least one subject from each group[1]	
Group I — Probability and Statistics, Combinatorics, Computer Science	
Group II — Numerical Analysis, Physical Mathematics, Fluid Mechanics	
Units in Departmental Program that also satisfy the General Institute Requirements	(12)
Unrestricted Electives	84
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

Theoretical mathematics (or "pure" mathematics) is the study of the basic concepts and structures that underlie the mathematical tools used in science and engineering. Its purpose is to search for a deeper understanding and an expanded knowledge of mathematics itself.

Traditionally, pure mathematics has been classified into three general fields: analysis, which deals with continuous aspects of mathematics; algebra, which deals with discrete aspects; and geometry. The undergraduate program is designed so that students become familiar with each of these areas. Students may also wish to explore such other topics as logic, number theory, complex analysis, geometry, and subjects within applied mathematics.

The subject 18.100B Analysis I is basic to the program. Since this subject is strongly proof-oriented, many students find an intermediate subject such as 18.06 Linear Algebra or 18.710 Abstract Linear Algebra useful as preparation.

The subject 18.701 Algebra I is more advanced and should not be elected until the student has had some experience with proofs (as in 18.100B or 18.710).

[1] A list of acceptable subjects is available in Room 2-108.

Bachelor of Science in Mathematics
Course XVIII
Theoretical Mathematics Option

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [1 subject can be satisfied by 18.03 in the Departmental Program]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	Units
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)	
Required Subjects:	72
18.03 Differential Equations, 12; 18.02	
18.100B Analysis I, 12; 18.03	
One of the following three subjects:	
18.101 Analysis II, 12; 18.100B, 18.701**	
18.102 Analysis II, 12; 18.100B	
18.103 Fourier Analysis — Theory and Applications, 12; 18.100B	
plus	
18.701 Algebra I, 12; 18.02	
18.702 Algebra II, 12; 18.701	
18.901 Introduction to Topology I, 12; 18.100B	
Restricted Electives:	36
An upper level Mathematics Seminar[1] (12 units)	
Two additional Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)	
Units in Departmental Program that also satisfy the General Institute Requirements	(12)
Unrestricted Electives	84
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	180

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

[1] These seminars are 18.104, 18.504, 18.704, 18.904, and 18.994.

Mathematics and computer science are closely related fields. Problems in computer science are often formalized and solved with mathematical methods, and it is likely that the most important problems currently facing computer scientists will be solved by researchers skilled in algebra, analysis, combinatorics, logic and/or probability theory, as well as computer science.

The purpose of this program is to educate students in precisely these areas. First, the program provides a broad background in mathematics, equivalent to that of the other mathematics options, but emphasizing areas of greatest application to computer science. Second, it provides a solid core of education in computer science, beginning with 6.001 Structure and Interpretation of Computer Programs, and 6.034 Artificial Intelligence. These are followed by either 6.002 Circuits and Electronics and 6.004 Computation Structures, which concentrate on the hardware aspects of computer science, or by 6.170 Laboratory in Software Engineering and 6.035 Computer Language Engineering, which concentrate on the software aspects. The program is completed with two advanced subjects, 18.404J Theory of Computation and 18.414J Theory of Algorithms, which provide an introduction to the most mathematically intensive branches of computer science.

Some flexibility is allowed in this program. For instance, students may, with permission, substitute 6.170 Laboratory in Software Engineering for the recommended subject 6.034 Artificial Intelligence, provided that they complete the 6.002—6.004 sequence and that they otherwise satisfy the Institute Science Distribution Requirement. Similarly, they may, with permission, substitute 18.063 Introduction to Algebraic Systems for 18.310 Principles of Applied Mathematics, and 18.701 Algebra I for 18.06 Linear Algebra.

Bachelor of Science in Mathematics with Computer Science Course XVIII-C

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 18.03 and 6.034 in the Departmental Program]	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program		**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		**111 or 117**
18.03	Differential Equations, 12; 18.02	
18.310	Principles of Applied Mathematics, 12; 18.02	
18.404J	Theory of Computation, 12; 18.310**	
6.001	Structure and Interpretation of Computer Programs, 15	
6.034	Artificial Intelligence, 12; 6.001	
One subject from each of the following pairs:		
18.410J	Introduction to Algorithms, 12; 6.001, 18.310**	
or		
18.414J	Theory of Algorithms, 12; 18.310**, 18.06**	
18.06	Linear Algebra, 12; 18.02	
or		
18.710	Abstract Linear Algebra, 12; 18.02	
One of the following two sequences:		
6.002	Circuits and Electronics, 15; 8.02, *18.03***	
6.004	Computation Structures, 15; 6.001, 6.002	
or		
6.170	Laboratory in Software Engineering, 12; 6.001	
6.035	Computer Language Engineering, 12; 6.170	
Restricted Electives:		**48**
Four additional Course 18 subjects, including subjects from at least three of the following areas: Algebra, Analysis, Logic, Probability, Numerical Analysis, and Combinatorics[1]		
Units in Departmental Program that also satisfy the General Institute Requirements		**(24)**
Unrestricted Electives		**48**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements		**183 or 189**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

1 A list of acceptable subjects is available in Room 2-108.

Inquiries

Inquiries regarding academic programs may be addressed to Joanne E. Murray, Undergraduate Mathematics Office, Room 2-108, MIT, Cambridge, Massachusetts 02139, (617) 253-2416.

The following information sheets are available in Room 2-108:

What Math Subject Shall I Take?
Careers in Mathematics
Thinking of Majoring in Mathematics?
Applied Mathematics: Sample Programs

Bachelor of Science in Mathematics
Course XVIII
Applied Mathematics Option

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 18.03 in the Departmental Program, plus appropriate subjects totaling	24
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 60

18.03 Differential Equations, 12; 18.02

18.310 Principles of Applied Mathematics, 12; 18.02

18.311 Principles of Applied Mathematics, 12; 18.03

One of the following two subjects:

18.04 Complex Variables with Applications, 12; 18.03

18.284 Introduction to Functions of a Complex Variable, 12; 18.03

One of the following two subjects:

18.06 Linear Algebra, 12; 18.02

18.421J Algorithmic Algebra and Number Theory, 12; 18.06*, 18.310*

Restricted Electives: 48

Four additional Course 18 subjects from the following two groups with at least one subject from each group[1]

Group I — Probability and Statistics, Combinatorics, Computer Science

Group II — Numerical Analysis, Physical Mathematics, Fluid Mechanics

Unrestricted Electives	84
Total Units Required for the S.B. Degree	360

*Alternate prerequisites are listed in the subject description.

1 A list of acceptable subjects is available in Room 2-108.

Bachelor of Science in Mathematics
Course XVIII
Theoretical Mathematics Option

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 18.03 in the Departmental Program, plus appropriate subjects totaling	24
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 72

18.03 Differential Equations, 12; 18.02

18.100B Analysis I, 12; 18.03

One of the following three subjects:

18.101 Analysis II, 12; 18.100B, 18.701*

18.102 Analysis II, 12; 18.100B

18.103 Fourier Analysis — Theory and Applications, 12; 18.100B

plus

18.701 Algebra I, 12; 18.02

18.702 Algebra II, 12; 18.701

18.901 Introduction to Topology I, 12; 18.100B

Restricted Electives: 36

An upper level Mathematics Seminar[1] (12 units)

Two additional Course 18 subjects of essentially different content, with the first decimal digit one or higher (24 units)

Unrestricted Electives	84
Total Units Required for the S.B. Degree	360

*Alternate prerequisites are listed in the subject description.

1 These seminars are 18.104, 18.504, 18.704, 18.904, and 18.994.

Bachelor of Science in Mathematics with Computer Science
Course XVIII-C

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement	72
Science Distribution Requirement can be satisfied by 18.03 and 6.034 in the Departmental Program, plus appropriate subjects totaling	12
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)

Required Subjects: 111 or 117

18.03 Differential Equations, 12; 18.02

18.310 Principles of Applied Mathematics, 12; 18.02

18.404J Theory of Computation, 12; 18.310*

6.001 Structure and Interpretation of Computer Programs, 15

6.034 Artificial Intelligence, 12; 6.001

One subject from each of the following pairs:

18.410J Introduction to Algorithms, 12; 6.001, 18.310*

or

18.414J Theory of Algorithms, 12; 18.310*, 18.06*

18.06 Linear Algebra, 12; 18.02

or

18.710 Abstract Linear Algebra, 12; 18.02

One of the following two sequences:

6.002 Circuits and Electronics, 15; 8.02, *18.03**

6.004 Computation Structures, 15; 6.001, 6.002

or

6.170 Laboratory in Software Engineering, 12; 6.001

6.035 Computer Language Engineering, 12; 6.170

Restricted Electives: 48

Four additional Course 18 subjects of essentially different content, including subjects from at least three of the following areas: Algebra, Analysis, Logic, Probability, Numerical Analysis, Combinatorics[1]

Unrestricted Electives	39 or 45
Total Units Required for the S.B. Degree	360

*Alternate prerequisites are listed in the subject description.

1 A list of acceptable subjects is available in Room 2-108.

Graduate Study

The Department offers programs covering a broad range of topics leading to the Doctor of Philosophy and the Doctor of Science. Numerous informal seminars, as well as a joint weekly mathematics colloquium sponsored alternately by MIT, Brandeis University, and Harvard University, supplement the subject offerings.

Candidates whose primary interest is in the field of **pure mathematics** ordinarily take most of their subjects in the Department. In addition to their advanced specialization, students are encouraged to acquire breadth by taking basic subjects in analysis, algebra, geometry, Lie theory, logic, and topology. Candidates whose primary interest is in **applied mathematics** are expected to acquire breadth by taking subjects in astrophysics, combinatorics, fluid dynamics, theoretical physics, numerical analysis, statistics, and the theory of computation. Students are encouraged to study important aspects of one or more engineering or scientific fields closely related to research in applied mathematics. Assistance or collaboration in problems in pure or applied mathematics, which are being investigated by members of the staff, may constitute part of a graduate student's program.

Entrance Requirements for Graduate Study

Students are expected to have one year of college-level natural science in addition to an undergraduate mathematics program approximating that of mathematics majors at MIT. Students may enter the applied mathematics program from any undergraduate field of concentration; however, special consideration is given to students with a strong scientific background.

Doctor of Philosophy and Doctor of Science

The basic requirements for these degrees are given in Chapter IV, and the details of the program are explained in a set of notes available from the Department. The first stage is to take subjects (normally 11 subjects totaling 132 hours of graduate credits) and to prepare for the general qualifying examination. Doctoral candidates are required to have a reading knowledge of mathematical French, German, Italian, or Russian.

For students in the **pure mathematics** program, the oral part of the general examination covers three areas chosen by the student in consultation with the Chairman of the Committee on Graduate Students. One of the three areas is examined in greater depth and normally becomes the field of specialization. The examiner in this area normally becomes the thesis advisor. The examination must be passed by the end of the second year.

For students electing the **applied mathematics** program, the basic objective is a proper balance of specialization and diversity. By the end of the first year of study, the degree candidate in consultation with an advisor must submit a "plan of study" for approval by the Applied Mathematics Committee. In addition to a list of subjects related to the major field, this plan must include the core curriculum, which assures familiarity with the basic concepts of applied mathematics. In order to achieve maximum flexibility, programs are considered individually.

The *Guideline of Study for Doctoral Candidates in Applied Mathematics,* which is distributed to entering students, provides more complete information on degree requirements, academic standards, and financial support.

In either the pure mathematics or applied mathematics program, after successfully passing the specific requirements set in the general examination, the student may officially begin thesis research under the supervision of a thesis advisor. The thesis must represent original research of high quality, done while a student at MIT, and should be finished by the end of the fourth year of graduate study. Upon submitting the thesis the student must pass an oral thesis examination.

Teaching and Research Assistantships

A limited number of fellowships and teaching and research assistantships are available. Normally, entering students who are offered financial aid are offered teaching assistantships and the assistantships are renewed so that students are supported for a total of four years. Entering students who have not been offered aid should not expect aid in later years.

Inquiries

Additional information regarding academic or research programs in mathematics, admissions, or financial aid, may be obtained from Phyllis Ruby, Graduate Mathematics Office, Room 2-233, MIT, Cambridge, Massachusetts 02139, (617) 253-2689.

Department of Physics

Robert Joseph Birgeneau, Ph.D.
Cecil and Ida Green Professor of Physics
Head of the Department

Professors

Michel Baranger, Ph.D.
Professor of Physics

Ulrich Justus Becker, Ph.D.
Professor of Physics
(On leave, fall)

George Bekefi, Ph.D.
Professor of Physics

John Winston Belcher, Ph.D.
Professor of Physics

George Bernard Benedek, Ph.D.
Alfred H. Caspary Professor of Physics and Biological Physics

Ahmet Nihat Berker, Ph.D.
Professor of Physics

Aron Myron Bernstein, Ph.D.
Professor of Physics

William Bertozzi, Ph.D.
Professor of Physics

Hale Van Dorn Bradt, Ph.D.
Professor of Physics

Bernard Flood Burke, Ph.D.
Professor of Physics
William A. M. Burden Professor of Astrophysics

Wit Busza, Ph.D.
Professor of Physics

Claude Roger Canizares, Ph.D.
Professor of Physics

Min Chen, Ph.D.
Professor of Physics

George Whipple Clark, Ph.D.
Professor of Physics
Breene M. Kerr Professor

Bruno Coppi, Ph.D.
Professor of Physics

Eric Richard Cosman, Ph.D.
Professor of Physics

Ronald Crosby Davidson, Ph.D.
Professor of Physics
(On leave, fall)

Peter Theodore Demos, Ph.D.
Professor of Physics
(On leave, spring)

Mildred Spiewak Dresselhaus, Ph.D.
Institute Professor
Professor of Physics and Electrical Engineering

Thomas Henderson Dupree, Ph.D.
Professor of Physics
and Nuclear Engineering

James Ludlow Elliot, Ph.D.
Professor of Physics and Astronomy
Director, George R. Wallace, Jr., Astrophysical Observatory

Bernard Taub Feld, Ph.D.
Professor of Physics

Michael Stephen Feld, Ph.D.
Professor of Physics
Director, Spectroscopy Laboratory

Anthony Philip French, Ph.D.
Professor of Physics

Jerome Isaac Friedman, Ph.D.
William A. Coolidge Professor of Physics
(On leave, spring)

Jeffrey Goldstone, Ph.D.
Cecil and Ida Green Professor of Physics
Director, Center for Theoretical Physics

Thomas John Greytak, Ph.D.
Professor of Physics

Lee Grodzins, Ph.D.
Professor of Physics
(On leave)

Alan Harvey Guth, Ph.D.
Professor of Physics

Kerson Huang, Ph.D.
Professor of Physics

Karl Uno Ingard, Ph.D.
Professor of Physics and Aeronautics and Astronautics
(On leave, fall)

Roman Wladimir Jackiw, Ph.D.
Professor of Physics

Robert Loren Jaffe, Ph.D.
Professor of Physics

Ali Javan, Ph.D.
Francis Wright Davis
Professor of Physics

John Dimitris Joannopoulos, Ph.D.
Professor of Physics

Kenneth Alan Johnson, Ph.D.
Professor of Physics

Paul Christopher Joss, Ph.D.
Professor of Physics

Marc Aaron Kastner, Ph.D.
Professor of Physics

Henry Way Kendall, Ph.D.
Professor of Physics

Arthur Kent Kerman, Ph.D.
Professor of Physics
Director, Laboratory for Nuclear Science

John Gordon King, Ph.D.
Francis Friedman Professor of Physics

Vera Kistiakowsky, Ph.D.
Professor of Physics
(On leave, fall)

Daniel Kleppner, Ph.D.
Lester Wolfe Professor of Physics
Associate Director, Research Laboratory of Electronics

George Fred Koster, Ph.D.
Professor of Physics

Stanley Benedict Kowalski, Ph.D.
Professor of Physics

Patrick A. Lee, Ph.D.
Professor of Physics
(On leave, spring)

Walter Hendrik Gustav Lewin, Dr.Tech.Sci.
Professor of Physics

James David Litster, Ph.D.
Professor of Physics
Director, Francis Bitter National Magnet Laboratory

Earle Leonard Lomon, Ph.D.
Professor of Physics

Francis Eugene Low, Ph.D.
Institute Professor
Professor of Physics

Margaret L. A. MacVicar, Sc.D.
Professor of Physical Science and Cecil and Ida Green Professor of Education
Dean for Undergraduate Education

June Lorraine Matthews, Ph.D.
Professor of Physics
(On leave)

Ernest Moniz, Ph.D.
Professor of Physics
Director, Bates Linear Accelerator

John William Negele, Ph.D.
Professor of Physics

Louis Shreve Osborne, Ph.D.
Professor of Physics

Gordon H. Pettengill, Ph.D.
Professor of Planetary Physics
Director, Center for Space Research

Irwin Abraham Pless, Ph.D.
Professor of Physics

Miklos Porkolab, Ph.D.
Professor of Physics

David Edward Pritchard, Ph.D.
Professor of Physics

Saul Alan Rappaport, Ph.D.
Professor of Physics

Lawrence Rosenson, Ph.D.
Professor of Physics

Toyoichi Tanaka, D.Sc.
Professor of Physics

Samuel C. C. Ting, Ph.D.
Professor of Physics
Holder of the Thomas Dudley Cabot Institute Chair

Felix Marc Hermann Villars, D.Sc.
Professor of Physics

Rainer Weiss, Ph.D.
Professor of Physics

Peter Adalbert Wolff, Ph.D.
Professor of Physics

Richard Kumeo Yamamoto, Ph.D.
Professor of Physics

James Edward Young, Ph.D.
Professor of Physics

Associate Professors

Edward Henry Farhi, Ph.D.
Associate Professor of Physics
(On leave, spring)

Ralph Leroy McNutt, Jr., Ph.D.
Associate Professor of Physics

Janos Polonyi, Ph.D.
Associate Professor of Physics

Robert Page Redwine, Ph.D.
Associate Professor of Physics
(On leave)

Assistant Professors

Edmund W. Bertschinger, Ph.D.
Assistant Professor of Physics
(On leave, fall)

Susan Cooper, Ph.D.
Assistant Professor of Physics

Katherine Freese, Ph.D.
Assistant Professor of Physics

John M. Graybeal, Ph.D.
Assistant Professor of Physics

Leonard Gregor Herten, Ph.D.
Assistant Professor of Physics

Mehran Kardar, Ph.D.
Assistant Professor of Physics

B. Gabriel Kotliar, Ph.D.
Assistant Professor of Physics

Robert Joseph Ledoux, Ph.D.
Assistant Professor of Physics

Aneesh Vasant Manohar, Ph.D.
Assistant Professor of Physics

Stephan Schutzmeister Meyer, Ph.D.
Class of 1942 Career Development
Assistant Professor of Physics

Simon Mochrie, Ph.D.
Assistant Professor of Physics

Jean-Pierre Charles Revol, Ph.D.
Assistant Professor of Physics

Steven W. Stahler, Ph.D.
Assistant Professor of Physics

John L. Tonry, Ph.D.
Assistant Professor of Physics

Jonathan S. Wurtele, Ph.D.
Assistant Professor of Physics

Barton Zwiebach, Ph.D.
Assistant Professor of Physics

Visiting Professor

Geoffrey Russell Court, Ph.D.
Professor of Physics

Senior Research Scientists

Roshan Lal Aggarwal, Ph.D.

Joseph Dennis Burger, Ph.D.

Thomas William Donnelly, Ph.D.

Simon Foner, D.Sc.

Alan Jay Lazarus, Ph.D.

Paul David Luckey, Jr., Ph.D.

Earl S. Marmar, Ph.D.

Stephen Geoffrey Steadman, Ph.D.

Edwin Floriman Taylor, Ph.D.

Frank E. Taylor, Ph.D.

Richard Temkin, Ph.D.

William Ernest Turchinetz, Ph.D.
Associate Director, Bates
Linear Accelerator

Claude Finley Williamson, Ph.D.

Principal Research Scientists

Edward S. Cheng, Ph.D.
Paul Stanley Linsay, Ph.D.
Peter Reed Saulson, Ph.D.

Lecturer

Frederic John Eppling, Ph.D.
Associate Director, Laboratory
for Nuclear Science

Technical Instructors

Hamid Arjomand, M.S.
Robert Mark Bessette
Eugene Michael diSalvatore, A.B.
Charles A. Forte
Jordan Kirsch, Ph.D.
Jan Orsula
David Robertson, B.S.
Thomas Joseph White, Jr.

Administrative Officer

Catherine Ormond, B.A.

Administrative Staff

Margaret Louise Berkovitz, B.A.
William John Billings, B.A.
Theodore Coleman
Lyle Hodgson
Gail Marlene Morchower, M.A.
Brenda Nace, B.S.
Kim Blakely Wainwright, B.A.

Postdoctoral Associates

Oscar Alerhand, Ph.D.
Joel Brock, Ph.D.
Gary L. Doll, Ph.D.
Stuart Field, Ph.D.
Jon Otto Fossum, Ph.D.
Sridhar Gorti, Ph.D.
Tai Kai Ng, Ph.D.
Israel Ohana, Ph.D.
Nickolas Read, Ph.D.
George M. Thurston, Ph.D.

Visiting Scientists

Thierry Dombre, Ph.D.
Jan Kallne, Ph.D.
Jack S. Goldstein, Ph.D.
Yasuo Y. Suzuki, Ph.D.

Professors Emeriti

William Phelps Allis, Sc.D.
Professor of Physics, Emeritus

Walter Carlisle Barber, Ph.D.
Professor of Physics, Emeritus

Alan Hildreth Barrett, Ph.D.
Professor of Physics, Emeritus

Herbert Sage Bridge, Ph.D.
Professor of Physics, Emeritus

Martin Deutsch, Ph.D., Sc.D.
Professor of Physics, Emeritus

Harald Anton Enge, Dr.Phil.
Professor of Physics, Emeritus

Robley Dunglison Evans, Ph.D.
Professor of Physics, Emeritus

Herman Feshbach, Ph.D.
Institute Professor, Emeritus
Professor of Physics, Emeritus

David Henry Frisch, Ph.D.
Professor of Physics, Emeritus

Albert Gordon Hill, Ph.D.
Professor of Physics, Emeritus

Robert Inslee Hulsizer, Jr., Ph.D.
Professor of Physics, Emeritus

Benjamin Lax, Ph.D.
Professor of Physics, Emeritus

Philip Morrison, Ph.D.
Institute Professor, Emeritus
Professor of Physics, Emeritus

Stanislaw Olbert, Ph.D.
Professor of Physics, Emeritus

Bruno Benedetto Rossi, Ph.D.
Institute Professor, Emeritus
Professor of Physics, Emeritus

Clifford Glenwood Shull, Ph.D.
Professor of Physics, Emeritus

Malcom Woodrow Pershing Strandberg, Ph.D.
Professor of Physics, Emeritus

Laszlo Tisza, Ph.D.
Professor of Physics, Emeritus

George Edward Valley, Ph.D.
Professor of Physics, Emeritus

Bertram Eugene Warren, Sc.D.
Professor of Physics, Emeritus

Victor Frederick Weisskopf, Ph.D., Sc.D.
Institute Professor, Emeritus
Professor of Physics, Emeritus

Department of Physics

(Course 8)

Undergraduate Study

The Department of Physics offers undergraduate, graduate, and postgraduate training, with a wide range of options for specialization.

The emphasis of both the undergraduate curriculum and the graduate programs is on understanding the fundamental principles that appear to govern the behavior of the physical world, from phenomena in the small-scale domain of subatomic particles to the large-scale structure of the universe, spanning a spatial range stretching from 10^{-16} cm to 10^{28} cm. At each level of structural organization, active and exciting areas of investigation abound. Topics range from the basic constituents of matter, atomic and nuclear structure, to thermonuclear plasmas, the physics at extremely low temperatures or extremely high pressures, to the evolution of stars, the large-scale structure of the universe, and the mystery of gravity.

The Department has extensive facilities for experimental research as described in the section on graduate study. Many of these are accessible to interested undergraduates, in the context of the Undergraduate Research Opportunities Program (UROP). Students are encouraged to enrich their curriculum by taking advantage of this opportunity.

Bachelor of Science in Physics Course VIII

An undergraduate degree in physics provides a good basis, not only for graduate study in physics and related fields, but also for professional work in such fields as astronomy, biophysics, engineering and applied physics, and geophysics. Many students have also found it to be an excellent preparation for subsequent graduate work in professional schools of medicine, law, and management. The undergraduate curriculum in physics offers students the opportunity to acquire basic competence in the fundamentals of both experimental and theoretical physics. The central core of requirements for the Bachelor of Science is designed not only to accomplish this objective but also to provide opportunity for students to select from a considerable variety of subjects and to proceed at the pace and degree of specialization best suited to their individual capabilities.

In the second year, a student will get a first exposure to 8.04 Quantum Physics I, and 8.044 Statistical Physics I. It is suggested that students take 6.071 Introduction to Electronics or 6.002 Circuits and Electronics, in order to acquire a familiarity with some topics in electrical engineering. This is also the year for a prospective physics major to take a project laboratory. The physics project labs, 8.11 or 8.12, are recommended as an introduction to experimentation in physics.

In the third year, students will normally take 8.13 and 8.14 Experimental Physics and 8.05 Quantum Physics II. Students should also begin to sign up for the restricted elective subjects, two in mathematics and at least one in physics. The subjects 18.04 Complex Variables with Applications (or 18.075 Advanced Calculus for Engineers) and 18.06 Linear Algebra are of particular interest to physics majors. Students planning to do graduate work will also want to begin the theoretical physics sequence, starting with 8.06 Mechanics II in the second term of their junior year. A variety of topical elective subjects in astrophysics, condensed matter, plasma and atomic physics, as well as nuclear and particle physics, allows the student to obtain a closer acquaintance with these fields.

Bachelor of Science in Physics Course VIII

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement	8
Science Distribution Requirement [2 subjects can be satisfied by 8.03 and 18.03 in the Departmental Program][1]	3
Laboratory Requirement[2]	1
TOTAL Subjects	17

PLUS

Departmental Program		**Units**
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		**102**
8.03	Physics III, 12; 8.02, 18.02	
18.03	Differential Equations, 12; 18.02	
8.04	Quantum Physics I[3], 12; 8.03**, 18.03	
8.044	Statistical Physics I, 12; 8.03, 18.03	
8.05	Quantum Physics II, 12; 8.04**	
8.13	Experimental Physics I, 15; 8.04**	
8.14	Experimental Physics II, 15; 8.04**, *8.05*	
	Thesis[4] (12 units)	
Restricted Electives:		**36**
Two subjects given by the Department of Mathematics beyond 18.03 (24 units)		
At least one subject given by the Department of Physics in addition to those listed above[5] (12 units)		
Units in Departmental Program that also satisfy the General Institute Requirements		**(24)**
Unrestricted Electives		**66**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements		**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

1
Students may find it advantageous to elect 6.071 Introduction to Electronics or 6.002 Circuits and Electronics in the second term of the second year, to complete the Science Distribution Requirement.

2
8.11 or 8.12 is suggested. The Institute Laboratory Requirement will not be satisfied by 8.13 or 8.14.

3
8.211 may substitute for 8.04.

4
A thesis of 12 units is required. Not more than 30 units of thesis credit may be included in the minimum of 180 units required for the S.B. degree beyond the General Institute Requirements.

5
Catalogue descriptions indicate subjects which cannot be used for this purpose. Students planning to do graduate work in physics would normally take the theoretical sequence 8.06, 8.07, and 8.08.

In the fourth year, the theoretical sequence can be continued with 8.07 Electromagnetism II and 8.08 Statistical Physics II. Students intending to continue with graduate studies in Physics are encouraged to take both parts of this theoretical physics sequence.

An important component of the physics program is the undergraduate thesis, which is a project carried out under the guidance of a faculty member. Many thesis projects in the recent past have grown out of the Undergraduate Research Opportunities Program. It is advisable that students have some idea of a thesis topic by the middle of their junior year; they are required to submit a thesis proposal prior to registering for 8.ThU. In order to introduce students to the research activities in the department, undergraduate physics colloquia are held weekly.

A relatively large amount of elective time usually becomes available during the fourth year and can be used effectively in a variety of ways, in physics or on other subjects.

The VIII-A Program: Physics with Electrical Engineering

This program, offered in cooperation with the Department of Electrical Engineering and Computer Science, is designed for students who wish to supplement the regular Physics curriculum with intensive study in the field of Electrical Engineering. Students completing this program receive the degree of Bachelor of Science in Physics and a letter from both participating departments certifying successful completion of this program.

The program should be of particular interest to physics majors who wish to broaden their career options after receiving the bachelor's degree and to those who plan graduate work in experimental physics. Students acquire a thorough foundation in both the theory and application of analog and digital electronic systems.

To receive certification, a student must complete the following subjects in addition to the **Required Subjects*** in the regular Physics program:

6.001	Structure and Interpretation of Computer Programs, 15
6.002	Circuits and Electronics, 15
6.003	Signals and Systems, 15
6.012	Electronic Devices and Circuits, 12
8.07	Electromagnetism II, 12

Depending upon career objectives, a student may wish to fulfill the Institute Laboratory Requirement by taking 6.111 Introductory Digital Systems Laboratory, 12.

Inquiries

Additional information concerning degree programs, admissions and financial aid may be obtained by writing to Professor Robert Redwine, c/o the Physics Undergraduate Office, Room 4-352, MIT, Cambridge, Massachusetts 02139, (617) 253-4841.

*Note that this program can be accomplished within the required 360 units for the S.B. degree.

Bachelor of Science in Physics Course VIII

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements		Total Units
Science Requirement		60
Humanities, Arts, and Social Sciences Requirement		72
Science Distribution Requirement can be satisfied by 8.03 and 18.03 in the Departmental Program, plus appropriate subjects totaling[1]		12
Laboratory Requirement[2]		12
Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		102
8.03	Physics III, 12; 8.02, 18.02	
18.03	Differential Equations, 12; 18.02	
8.04	Quantum Physics I[3], 12; 8.03**, 18.03	
8.044	Statistical Physics I, 12; 8.03, 18.03	
8.05	Quantum Physics II, 12; 8.04**	
8.13	Experimental Physics I, 15; 8.04**	
8.14	Experimental Physics II, 15; 8.04**, *8.05*	
	Thesis[4] (12 units)	
Restricted Electives:		36
Two subjects given by the Department of Mathematics beyond 18.03 (24 units)		
At least one subject given by the Department of Physics in addition to those listed above[5] (12 units)		
Unrestricted Electives		66
Total Units Required for the S.B. Degree		360

**Alternate prerequisites are listed in the subject description.

1 Students may find it advantageous to elect 6.071 Introduction to Electronics or 6.002 Circuits and Electronics in the second term of the second year, to complete the Science Distribution Requirement.

2 8.11 or 8.12 is suggested. The Institute Laboratory Requirement will not be satisfied by 8.13 or 8.14.

3 8.211 may substitute for 8.04.

4 A thesis of 12 units is required. Not more than 30 units of thesis credit may be included in the minimum of 360 units required for the S.B. degree.

5 Catalogue descriptions indicate subjects which cannot be used for this purpose. Students planning to do graduate work in physics would normally take the theoretical sequence 8.06, 8.07, and 8.08.

Graduate Study

The Department offers programs leading to the degree of Master of Science in Physics, Doctor of Philosophy, and the Doctor of Science.

Master of Science in Physics

The requirements for the Master of Science in Physics are the General Institute Requirements listed in Chapter IV. The master's thesis must represent a piece of independent research work, in any of the fields described below, and carried out under the supervision of a Department faculty member. No fixed time is set for the completion of a master's program; two years of work is a rough guideline. There is no language requirement for this degree.

Doctor of Philosophy and Doctor of Science

Candidates for the Doctor of Philosophy or Doctor of Science are expected to enroll in those basic graduate subjects that will prepare them for the General Examination, which must be passed no later than in the sixth term after initial enrollment. No specific subjects of study are prescribed, except for the requirement of two subjects outside the candidate's field of specialization (breadth requirement). There is no language requirement. The doctoral thesis must represent a substantial piece of original research, carried out under the supervision of a Department faculty member.

The Department faculty offer subjects of instruction, and are engaged in research in a variety of fields in experimental and theoretical physics. This broad spectrum of activities is organized in the divisional structure of the Department, presented below. Graduate students are encouraged to contact faculty in the division of their choice to inquire about opportunities for research, and to pass through an apprenticeship (by signing up for "Special Problems in Graduate Physics") as a first step toward an engagement in independent research for a doctoral thesis.

Research Divisions

The **Astrophysics Division** of the Department has a varied program of ground-based and satellite observations across the entire electromagnetic spectrum, with principal emphasis on the radio, optical, and X-ray parts, where state-of-the-art detectors are used. This work is complemented by theoretical work emphasizing high-energy phenomena, stellar evolution and galactic structure. Astrophysical plasmas are also an important area of study, both through the use of space probes and by complementary theoretical study. Research in astrophysics is a rapidly growing field at MIT, and, because of the strongly interdisciplinary and interdepartmental character of work in this area, a fuller description of it is found in the section entitled Astronomy and Astrophysics in Chapter VI.

Research activities in the **Division of Nuclei and Particles** include the broad fields of nuclear reaction and heavy ion physics, intermediate-energy nuclear structure physics, and high-energy fundamental particle physics. The experimental research in these areas is based on MIT's 800 MeV Bates Linear Accelerator and on the accelerators at Brookhaven National Laboratory, the Fermi National Accelerator Laboratory in Batavia, Illinois, the Stanford Linear Accelerator, CERN (Geneva), the electron-positron collider at DESY (Hamburg, Germany), and the Gran Sasso underground laboratory at Frascati (Italy).

The large and active program in **Solid-State, Laser, Plasma, and Atomic Physics** provides students with ample opportunities for study and research in these fields. Equipment is available for spectroscopic studies at radio, microwave, infrared, and optical frequencies. Currently available are facilities for the production of low temperatures, high pressures, and magnetic fields up to 100,000 gauss and for the study of matter using neutron diffraction techniques. A magnet capable of producing a steady magnetic field of 250,000 gauss is available at the Bitter National Magnet Laboratory. The 5,000 kW MIT Research Reactor is used for neutron diffraction studies, and the extensive facilities of the Information Processing Center and the Laboratory for Computer Science are available for research involving high-speed computation.

The chief emphasis of the **Nuclear and Particle Theory** research at the Center for Theoretical Physics is on understanding the fundamental particles of nature, as revealed by their interactions and by their decay, and on the characteristic quantum modes of motion of systems composed of strongly interacting particles such as atomic nuclei. Work is also conducted on theoretical astrophysics, as well as on the properties of other forms of matter. In all of this research, close contact is maintained with experimentalists, both within MIT and elsewhere.

The Center for Theoretical Physics houses a fairly large group of theorists including professional staff, postdoctoral fellows, senior visitors, and graduate students engaged in research in theory. Opportunities for communication and collaboration are maximized within the Center; lively interaction among the many specialists in the various areas of interest is characteristic of this MIT group and is one of the major sources of the Center's strength.

Much of the research in the Department is carried out as part of the work of various interdepartmental laboratories and centers, including the Laboratory for Nuclear Science, the Research Laboratory of Electronics, the Spectroscopy Laboratory, the Center for Materials Science and Engineering, the Center for Space Research, the Bitter National Magnet Laboratory, the Plasma Fusion Center, and the Program on Sciences and Technology and International Security. These facilities, most of which are described in Chapter VI, provide close relationships among the research activities of a number of MIT departments and give students opportunities for contact with research carried out in disciplines other than physics.

Entrance Requirements for Graduate Study

Students intending to pursue graduate work in physics should have as a background the equivalent of the requirements for the Bachelor of Science in Physics from MIT. However, some deficiencies may be removed in the course of graduate work.

Inquiries

Additional information on degree programs, research activities, admissions, financial aid, teaching and research assistantships may be obtained by writing to Professor George F. Koster, Physics Graduate Office, Room 6-107, MIT, Cambridge, Massachusetts 02139, (617) 253-4851.

Program in Applied Biological Sciences

(Course 20)

Graduate Study

Applied biological sciences at MIT comprise education and research in three broad areas: toxicology, biotechnology, and biochemistry. Beginning with the academic year 1988-89, these activities will be found in a number of academic units at MIT, rather than organized in a single department. Students *currently* enrolled in the Program pursue degree programs described below. *New or prospective* students interested in these fields of study should make inquiries through the departments listed below.

Biochemistry programs include studies in applied enzymology, genetics, molecular biology of photosynthesis, protein and amino acid metabolism, carcinogen metabolism and binding to macromolecules, and synthesis and structure of oligonucleotides. Faculty whose work focuses on Biochemistry hold appointments in the School of Science, the Department of Chemistry, and the Whitaker College.

Programs in **Biotechnology** devise improved means of drug delivery, apply fundamental concepts of chemical engineering from bacterial to human cell production systems; and use modern techniques in organic chemistry and molecular biology to create more useful biological products. Biotechnology activites are located in the Departments of Biology, Chemistry, Chemical Engineering, and with faculty affiliated with the School of Science, the Harvard-MIT Division of Health Sciences and Technology, and the Office of the Provost.

Toxicology includes studies in environmental carcinogenesis, metabolism of foreign compounds, genetic toxicology, molecular aspects of interactions of mutagens and carcinogens with nucleic acids and proteins, molecular cloning and characterization of transformation effector and suppressor genes. The programs in toxicology are housed in the Whitaker College.

Undergraduate Curriculum in Applied Biology — Course VII-B

The undergraduate curriculum in Applied Biology (VII-B) is available to students who entered MIT prior to 1987. The curriculum emphasizes interdisciplinary laboratory and class experience in the physical and biological sciences. A more detailed description of the requirements for Course VII-B can be found under the Department of Biology.

Graduate work in Applied Biological Sciences may lead to the Master of Science, Doctor of Philosophy, or Doctor of Science in the fields described earlier.

Master of Science

The S.M. degree is awarded in Applied Biological Sciences and in Biochemical Engineering. The requirements for the S.M. include Departmental entrance subjects, and at least two "A" level elective graduate courses.

A total of 66 subject units (42 of which must be 'A' level) is required for the S.M. Both S.M. programs require a thesis of at least 24 units, carried out under the direction of a faculty member affiliated with the Program.

Doctor of Philosophy and Doctor of Science

The requirements for the Ph.D/Sc.D. in Applied Biological Sciences are similar to those for the S.M., except regarding electives. Doctoral students must take at least four courses in an area of specialization that are to be determined in consultation with the advisor. The course requirements for the Ph.D./Sc.D. in Biochemical Engineering are identical to those for the S.M. Both programs require an original thesis.

Written doctoral qualifying and general examinations, usually taken after the second term for students in Applied Biological Sciences and after the third term for those in Biochemical Engineering, establish competence with reference to a basic scientific background as well as in specialized areas of knowledge related to the specific degree programs. The written examination is followed by an oral presentation and defense of a research proposal on which the thesis research is to be based.

Thesis research is done under the supervision of faculty members in the various areas of specialization described earlier. Research progress is evaluated periodically by the thesis advisory committee, which also hears the student's oral defense of the completed thesis.

Inquiries

For information about particular programs and affiliated faculty, please contact Professor Steven Tannenbaum or Debra Luchanin in the Student Office, Room 16-330, (617) 253-5804.

Faculty and Instructor Affiliated with the Program in Applied Biological Sciences (by area of specialization)

Biochemistry

Alexander M. Klibanov, Ph.D.
Professor of Chemistry
Department of Chemistry

Steven Robert Tannenbaum, Sc.D.
Professor of Chemistry
Professor of Toxicology
Department of Chemistry and Whiatker College

Gerald Norman Wogan, Ph.D.
Underwood-Prescott Professor of Chemistry
Professor and Director, Program in Toxicology
Department of Chemistry and Whitaker College

Vernon R. Young, Ph.D., D.Sc.
Professor of Nutritional Biochemistry
Clinical Research Center and School of Science

John Martin Essigmann, Ph.D.
Associate Professor of Chemistry
Associate Professor of Toxicology
Department of Chemistry and Whitaker College

Douglas C. Youvan, Ph.D.
Atlantic Richfield Assistant Professor of Chemistry
Department of Chemistry

Biotechnology

Charles Leland Cooney, Ph.D.
Professor of Chemical and Biochemical Engineering
Department of Chemical Engineering

Arnold Lester Demain, Ph.D.
Professor of Industrial Microbiology
Department of Biology

Samuel Abraham Goldblith, Ph.D.
Professor of Food Science
Vice President, Resource Development, Emeritus
Senior Advisor to the President

Marcus Karel, Ph.D.
Professor of Chemical and Food Engineering
Department of Chemical Engineering

Alexander M. Klibanov, Ph.D.
Professor of Chemistry
Department of Chemistry

Robert Samuel Langer, Ph.D.
Professor of Chemical and Biomedical Engineering
Department of Chemical Engineering

Robert Spencer Leos, M.D.
Professor of Health Sciences and Technology
Harvard-MIT Division of Health Sciences and Technology

Anthony John Sinskey, Sc.D.
Professor of Applied Microbiology
Department of Biology

William G. Thilly, Sc.D.
Professor of Applied Biology
Program in Toxicology, Whitaker College
Director, Center for Environmental Health Sciences

Daniel I. C. Wang, Ph.D.
Chevron Professor of Chemical Engineering
Department of Chemical Engineering
Director, Biotechnology Process Engineering Center

Cho Kyun Rha, Sc.D.
Associate Professor of Biomaterials Science and Engineering
Office of the Provost
Biomaterials Science and Engineering Laboratory

Marie B. Chow, Ph.D.
Assistant Professor of Biology
Department of Biology

Kim Lewis, Ph.D.
Assistant Professor of Biology
Department of Biology

Cato T. Laurencin, M.D., Ph.D.
Instructor of Biochemical Engineering
Harvard-MIT Division of Health Sciences and Technology and School of Science

Toxicology

Gerald Norman Wogan, Ph.D.
Underwood-Prescott Professor of Chemistry
Professor and Director, Program in Toxicology
Department of Chemistry and Whitaker College

James G. Fox, D.V.M.
Professor and Director, Division of Comparative Medicine

Steven Robert Tannenbaum, Sc.D.
Professor of Chemistry
Professor of Toxicology
Department of Chemistry and Whitaker College

William G. Thilly, Sc.D.
Professor of Applied Biology
Program in Toxicology, Whitaker College
Director, Center for Environmental Health Sciences

John Martin Essigmann, Ph.D.
Associate Professor of Chemistry
Associate Professor of Toxicology
Department of Chemistry and Whitaker College

Helmut Zarbl, Ph.D.
Assistant Professor of Toxicology
Whitaker College

The Whitaker College of Health Sciences, Technology, and Management





In 1977, MIT established the Whitaker College of Health Sciences, Technology, and Management to provide a major academic and administrative focus for the extensive development of health-related activities at the Institute. The College represents a major commitment by MIT to marshal its resources and strengths in science and engineering, in order to foster progress in the biological and health sciences and to improve the quality of health care. Since health-related activities in education and research transcend the concerns of any single department or School of the Institute, the term "college" is being used for the first time at MIT.

The concept of Whitaker College derives from MIT's belief that biomedical and health-related problems are complex in nature and require the combined efforts of a wide range of disciplines for their ultimate solution. These disciplines include not only biology and chemistry, but also physics, mathematics, various branches of engineering, and computer science. Faculty members involved in the educational and research programs of Whitaker College hold joint appointments in the College and in other Schools, departments, and interdisciplinary laboratories at MIT.

The director of Whitaker College is Dr. Emilio Bizzi, Eugene McDermott Professor in the Brain Sciences and Human Behavior.

In defining the programmatic objectives of Whitaker College, MIT has sought to identify the fields in which the College can play an especially effective role by developing new activities, fortifying existing programs, and amplifying opportunities for faculty members and students. The College has identified five intellectual foci, which now serve as the basis for its divisions. These are the recently formed Department of Brain and Cognitive Sciences, the program in Biological and Medical Imaging, the Program in Toxicology, the Clinical Research Center, and the Center for Environmental Health Sciences. Several graduate programs are being developed in the College. The Department of Brain and Cognitive Sciences has Ph.D. programs in neuroscience, computation, and cognition. The program in Biological and Medical Imaging is linked with the Ph.D. in Radiological Sciences, which is operated under the joint auspices of the College and the Department of Nuclear Engineering. A graduate degree program in Toxicology in the Whitaker College is under development. The Clinical Research Center is MIT's major locus for investigations on human subjects. A more detailed description appears in Chapter VI of this Bulletin.

The Doctoral Program in Brain and Cognitive Sciences

The recently formed Department of Brain and Cognitive Sciences, created by a merger of the Department of Psychology with previously existing programs in Whitaker College, offers graduate study leading to doctoral degrees in the brain sciences and the cognitive sciences.

This department enhances MIT's ongoing interdisciplinary efforts to understand the human brain. The study of the complexities of the brain requires an approach combining the experimental technologies of neurobiology and psychology with the theoretical power coming from the fields of artificial intelligence and linguistics. Graduate students in the doctoral program in brain and cognitive sciences follow a curriculum that affords the opportunity for broad study in a variety of relevant fields.

A more detailed description of the graduate program in brain and cognitive sciences appears on the following pages.

The Doctoral Program in the Radiological Sciences

The graduate program in the Radiological Sciences is a four- to five-year commitment leading to the Ph.D. or Sc.D. degree. The program encompasses ionizing radiation and more recent technologies, such as ultrasound, lasers, and nuclear magnetic resonance. Students in Radiological Sciences pursue their academic and research objectives in one of four specialty areas: medical diagnostic and therapeutic technology, radiation biophysics, radiopharmaceutical chemistry, and biological and medical image processing. While most core subjects will be taken at MIT, student research can be conducted at Harvard-affiliated hospitals, the Harvard School of Public Health, and at MIT in the Magnetic Resonance Imaging Facility of the National Magnet Laboratory and the Image Processing Facility of Whitaker College.

In the area of medical diagnostic and therapeutic technology, students will probe questions and methodologies that can have an impact on the identification and treatment of human disease.

Radiation biophysics research focuses upon radiation effects at the cellular and sub-cellular levels in order to better understand the basic biological response to irradiation. Radiation biophysics studies include efforts at the electron microscope level and an emphasis on physical mechanisms in radiation action.

Radiopharmaceutical chemistry is a rapidly expanding discipline due to the many recent breakthroughs in nuclear medicine and isotope use in biology. MIT and Harvard-affiliated hospitals offer outstanding research facilities in this area of study.

Image processing in biology and medicine combines image data with powerful digital computer processing and graphical display. Data sources include two-dimensional information from computer tomography, magnetic resonance imaging, transmission and scanning electron, and optical microscopy. The ability to manipulate three-dimensional objects via human interactive computer graphics has revolutionized engineering design, chemical synthesis, and folding attributes of biological molecules. The Biological and Medical Imaging Processing Facility is organized to develop and offer comparable power to investigators interested in morphological, structural, developmental, metabolic, and other questions that can be interpreted through three-dimensional implementation and manipulation.

Undergraduate preparation for acceptance into the Radiological Sciences Program requires a bachelor's degree in physical science or engineering. Additional preparation in computer science and biochemistry is highly recommended. The GRE aptitude test and one advanced test are also recommended. At the baccalaureate level, students should apply for admission to the MIT Department of Nuclear Engineering in order to pursue a graduate program leading to a master's degree in nuclear engineering. Students entering the program with their master's degree must complete the Radiological Sciences core subject requirements during the initial phase of their program or demonstrate competence in the required subject areas.

A qualifying examination assessing general radiological sciences preparation plus material relevant to the student's specialty area must be passed prior to the initiation of doctoral research. For those entering with an S.B., this exam is taken at the end of the second year. Doctoral research will require an additional two or three years and concludes with a thesis defense before Nuclear Engineering Department faculty, supplemented with Whitaker College and other faculty as appropriate.

The Doctoral Program in Toxicology

MIT has offered Ph.D., Sc.D., and S.M. degrees in toxicology through the Department of Applied Biological Sciences for over 15 years. Whitaker College plans to offer graduate degree programs in toxicology beginning in 1989.

In its teaching and research endeavors, the program is focused on understanding how the interactions of organisms with chemical and phsyical agents in the environment induce toxicity and pathogenesis, with the goal of understanding the origins of genetic disease in humans. The program represents an interface among the Departments of Chemistry and Biology in the School of Science as well as the Departments of Chemical, Nuclear, and Civil Engineering. In this position, it plays a pivotal role in fostering the development of interdisciplinary research programs among a variety of laboratories.

The core curriculum of the program is designed to provide rigorous training in the basic sciences, with particular emphasis on chemistry, biochemistry, molecular biology, genetics, toxicology, and pharmacology. Students will receive preparation for careers involving the application of modern methods of chemical, molecular, biological, and genetic analysis to risk assessment in the chemical, biotechnological, pharmaceutical, food, and nuclear industries. Faculty members are drawn from a wide range of disciplines and hold joint appointments in the Departments of Chemistry, Biology, and several departments in the School of Engineering. The members of the program also form the nucleus for the MIT Center for Environmental Health Sciences.

Curricula are arranged to permit flexibility, and opportunities exist for interdisciplinary training. Students may be admitted directly into the program, or may be admitted through departments in which faculty members hold joint appointments. The first two regular terms are spent mainly in course work. The latter include laboratory courses in which students rotate through the laboratories of the faculty members in the program. Students are then admitted to their laboratory of preference to begin full-time work towards a thesis in an area of specialization. Doctoral examinations, both written and oral, must be taken no later than the fourth semester of full-time graduate study. Thesis research normally requires two to three years of full-time research activity after the examinations are successfully completed.

Areas of research specialization within the program include studies in environmental carcinogenesis, development of molecular methods for direct measurement of mutagenesis in humans, metabolism of foreign compounds, genetic toxicology, the molecular aspects and

dosimetry of interactions between mutagens and carcinogens with nucleic acids and proteins, molecular mechanism of DNA damage and repair, design and mechanism of action of chemotherapeutic agents, molecular mechanisms of carcinogenesis, virology, molecular biology of oncogenes, and cell physiology.

Toxicology subjects are numbered 20.611 — 20.618 in Chapter VIII of this catalogue. For additional information, please contact Professor Gerald N. Wogan, Director of the Toxicology Program, at (617) 253-3159.

Faculty and Staff in the Whitaker College

Emilio Bizzi, M.D.
Eugene McDermott Professor in the Brain Sciences and Human Behavior
Director

Robert W. Mann, Sc.D.
Whitaker Professor of Biomedical Engineering
Department of Mechanical Engineering
Director of Biomedical Engineering Programs

Derek Rowell, Ph.D.
Associate Professor of Mechanical Engineering
Department of Mechanical Engineering
Director, Biological Imaging Facility

Professors

Gordon L. Brownell, Ph.D.
Professor of Nuclear Engineering
Department of Nuclear Engineering

Robert Samuel Langer, Sc.D.
Professor of Biochemical Engineering
Department of Chemical Engineering

Robert Daniel Rosenberg, M.D., Ph.D.
Professor of Medicine and Biology
Department of Biology

Associate Professor

Monty Krieger, Ph.D.
Latham Family Associate Professor of Molecular Genetics
Department of Biology

Assistant Professor

Van J. Wedeen, M.D.
Assistant Professor of Biological and Medical Imaging

Lecturer

Stan N. Finkelstein, M.D.
Senior Lecturer, Health Policy Management

Visiting Scientist/Scholar

Pauline Filipek, M.D.

Administrative Staff

Vera J. Ballard, B.A., C.S.S.
Assistant Director for Finance and Administration

Katherine Eisenhaure
Program Manager, Health Policy Management

Edward J. Gaudiano, M.S.
Facilities Officer

Maria T. Heyward
Assistant to the Director

Leonardo C. Topa, Ph.D.
Director of Computing

Thomas Turner
Computer Systems Coordinator

Faculty and Staff in the Program in Toxicology

Gerald Norman Wogan, Ph.D.
Underwood-Prescott Professor of Chemistry
Professor of Toxicology
Director, Program in Toxicology, Whitaker College
Department of Chemistry

Professors

James G. Fox, D.V.M.
Professor of Comparative Medicine
Director, Division of Comparative Medicine
Program in Toxicology, Whitaker College

Steven Robert Tannenbaum, Ph.D.
Professor of Chemistry
Professor of Toxicology
Registration and Admissions Officer
Program in Toxicology, Whitaker College
Department of Chemistry

William G. Thilly, Sc.D.
Professor of Applied Biology
Program in Toxicology, Whitaker College
Director, Center for Environmental Health Sciences

Associate Professor

John Martin Essigmann, Ph.D.
Associate Professor of Chemistry
Associate Professor of Toxicology
Program in Toxicology, Whitaker College
Department of Chemistry

Assistant Professor

Helmut Zarbl, Ph.D.
Assistant Professor of Toxicology
Program in Toxicology, Whitaker College

Principal Research Scientist

John Sherman Wishnok, Ph.D.

Research Scientists

William Fisher Busby, Ph.D.
Gerald McMahon, Ph.D.
Lata Shirname-More, Ph.D.
Paul Skipper, Ph.D.

Research Associate

W. Sara Stillwell, Ph.D.

Postdoctoral Associates

Ashis Basu, Ph.D.
Manjit Dosanjh, Ph.D.
Liang-Shang Gan, Ph.D.
Collette Hodes, Ph.D.
Phouthone Keohavong, Ph.D.
Youngsoo Kim, Ph.D.
Stephen Naylor, Ph.D.
Roberta Pastorelli, Ph.D.
Arun Kumar Rishi, Ph.D.
Michael Wood, Ph.D.

Postdoctoral Fellows

Wendy Heiger-Bernays, Ph.D.
Neela Soman, Ph.D.

Administrator for Academic Programs

Debra A. Luchanin, Ed.M.

Administrative Officer

Carla Welch Kirmani

Additional faculty and staff in the Whitaker College are listed with the Department of Brain and Cognitive Sciences on the following page.

Department of Brain and Cognitive Sciences

Emilio Bizzi, M.D.
Eugene McDermott Professor in the Brain Sciences and Human Behavior
Director, Whitaker College of Health Sciences, Technology, and Management
Head of the Department

Professors

Susan E. Carey, Ph.D.
Professor of Experimental Psychology
(On leave)

Stephan Lewis Chorover, Ph.D.
Professor of Psychology

Suzanne Corkin, Ph.D.
Professor of Psychology

Ann Martin Graybiel, Ph.D.
Professor of Neuroanatomy

Alan Hein, Ph.D.
Professor of Experimental Psychology

Richard Held, Ph.D.
Professor of Experimental Psychology

Nelson Yuan-Sheng Kiang, Ph.D.
Eaton-Peabody Professor of Communication Sciences

Daniel Nathan Osherson, Ph.D.
Professor of Psychology

Tomaso Armando Poggio, Ph.D.
Uncas and Helen Whitaker Professor of Vision Sciences and Biophysics
Codirector, Center for Biological Information Processing

Mary Crawford Potter, Ph.D.
Professor of Psychology

Whitman Albin Richards, Ph.D.
Professor of Psychophysics

Peter Harkai Schiller, Ph.D.
Dorothy W. Poitras Professor in Medical Engineering and Medical Physics

Gerald Edward Schneider, Ph.D.
Professor of Neuroscience

Shimon Ullman, Ph.D.
Professor of Psychology
(On leave)

Kenneth N. Wexler, Ph.D.
Professor of Psychology and Linguistics

Richard Jay Wurtman, M.D.
Professor of Neuropharmacology
Director, Clinical Research Center

Associate Professors

Edward H. Adelson, Ph.D.
Associate Professor of Visual Sciences
Department of Brain and Cognitive Sciences and the Media Arts and Sciences Section

Richard Alan Andersen, Ph.D.
Associate Professor of Neuroscience

John Hollerbach, Ph.D.
Associate Professor of Psychology

Ronald Davies Graham McKay, Ph.D.
Associate Professor of Neurobiology

Steven Pinker, Ph.D.
Associate Professor of Psychology
Codirector, Center for Cognitive Science

William G. Quinn, Ph.D.
Associate Professor of Neurobiology

Marc H. Raibert, Ph.D.
Associate Professor of Motor Control
Department of Brain and Cognitive Sciences and Electrical Engineering and Computer Science

Mriganka Sur, Ph.D.
Associate Professor of Neuroscience

Jeremy Michael Wolfe, Ph.D.
Associate Professor of Psychology

Assistant Professors

Christopher Granger Atkeson, Ph.D.
Assistant Professor of Motor Control

Ellen C. Hildreth, Ph.D.
Assistant Professor of Vision Science
Codirector, Center for Biological Information Processing

Michael I. Jordan, Ph.D.
Assistant Professor of Psychology

Arthur Douglas Lander, Ph.D., M.D.
Edward J. Poitras Assistant Professor in Human Biology and Experimental Medicine

Hermann Steller, Ph.D.
Assistant Professor of Neurobiology

Lecturers

Jerrold Bernstein, M.D.

Ray W. Fuller, Ph.D.
(Visiting)

John Growdon, M.D.

Timothy J. Maher, Ph.D.

Dermot O'Rourke, Ph.D.

Donald L. Schomer, M.D.
(Visiting)

Instructor

Naomi Fukagawa, M.D., Ph.D.

Visiting Scholars/Scientists

William K. Abend, M.D.
Kwang Wook Choi
Samuel A. Ellias, M.D., Ph.D.
Nancy L. Etcoff, Ph.D.
Henry H. Schmidek, M.D.
Eliot Spindel, Ph.D.
Ruth H. Walker, M.D.

Technical Instructors

Henry Hall, S.B.
Diane Major

Principal Research Scientists

Joseph Aloysius Bauer, Jr., M.S.
Sonal Jhaveri, Ph.D.

Research Associates/Engineers/Scientists

Benjamin Morgan Dawson, Ph.D.
Rhea Diamond Gendzier, Ph.D.
Jane Gwiazda, Ph.D.
Sonal Jhaveri, Ph.D.
Harris R. Lieberman, Ph.D.
Harry Lynch, Ph.D.
T. John Rosen, Ph.D.
Janet C. Sherman, Ph.D.
Judith Hirschhorn Wurtman, Ph.D.

Postdoctoral Associates/Fellows

Ian N. Acworth, Ph.D.
Guillermina Almazan, Ph.D.
Shabtai Barash, Ph.D.
Rifat Levent Buyukuysal, Ph.D.
Thomas R. Corisi, Ph.D.
Alice Cronin-Golomb, Ph.D.
Peter F. Drain, Ph.D.
Roger Erickson, Ph.D.
Reha S. Erzurumlu, Ph.D.
Leonardo Fogassi, Ph.D.
Elisabeth Folkers, Ph.D.
Jose Manuel Gimenez-Amaya, Ph.D.
Simon Giszter, Ph.D.
Bernard F. Godley, Ph.D.
Jody E. Green, Ph.D.
Norberto Grzywacz, Ph.D.
Masuad Hussian, Ph.D.
Mark E. Johnson, Ph.D.
Bruce Andrew Kay, Ph.D.
Blandine LaFerrere, M.D.
Ronald Bruce Langdon, Ph.D.
Urban L. Lendahl, Ph.D.
Nikolaos Logothetis, Ph.D.
Lina Massone, Ph.D.
Ferdinando Mussa-Ivaldi, Ph.D.
Sarah Pallas, Ph.D.
U. Ingrid Richardson, Ph.D.
Eric Schaeffer, Ph.D.
Jeffrey D. Schall, Ph.D.
Janell Schweickert, Ph.D.
Barbara Ellen Slack, Ph.D.
Daphna Weinshall, Ph.D.
Kristin White, Ph.D.
Jerry Chi-Ping Yin, Ph.D.

Administrative Staff

Janice Ellertsen
Academic Administrator

Andrea Hatch
Financial Administrator

Judith Rauchwarger, Ph.D.

Professor Emeritus

Walle Jetze Harinx Nauta, M.D., Ph.D.
Institute Professor, Emeritus

Department of Brain and Cognitive Sciences

(Course 9)

Undergraduate Study

The study of mind, brain, and behavior has grown in recent years with unforeseen rapidity. New avenues of approach, opened by developments in the biological and computer sciences, raise the hope that human beings, who have achieved considerable mastery over the world around them, may also come closer to an understanding of themselves. The goal of the Department of Brain and Cognitive Sciences is to answer fundamental questions concerning the nature of brain function and intelligence. To this end, the Department focuses on four themes: neurobiology, neuroscience, computation, and cognition.

Research in neurobiology deals with the biology of neurons, emphasizing the special properties of neurons as encoders, transmitters, and processors of information. A detailed understanding of neuronal structure and functions requires application of the techniques of contemporary molecular, cellular, and developmental biology. Application of these technologies is leading to exciting studies about the nervous system, providing new understanding of fundamental mechanisms of brain function. In addition, these studies have profound clinical implications, in part by generating a framework for the treatment of neurological and psychiatric disorders. Primary areas of interest include the development of neuronal morphology and connectivity, the cellular and molecular bases of behavior in simple neuronal circuits, neurochemistry, and cellular physiology.

In the area of systems neuroscience, departmental investigators use a number of new approaches ranging from computation to electrophysiology and biophysics. Of major interest are the visual and motor systems, where the scientific goals are to understand transduction and encoding of sensory stimuli into nerve messages, the organization and development of sensory-motor systems, the processing of sensory-motor information, and the sensory-motor performance of organisms. Also of major interest is neural and endocrine regulation, where the scientific goal is to understand the effects of circulating compounds on brain composition and behavior.

In computational neuroscience, a particularly strong interaction exists between the Department and the Artificial Intelligence Laboratory, providing new intellectual thrust in a number of areas in the neural and cognitive sciences including vision and motor control. Computational theories are developed and tested within the framework of neurophysiological, psychological, and other experimental approaches. In vision research, in addition to theoretical work addressing problems that any visual system must solve, there is complementary experimental work on the electrophysiology of visual cells at various relay stations and on the development of patterned vision and stereopsis. Work on motor control is also strongly interdisciplinary. Basic research activities include studying the relationships between multiple sensory inputs and complex motor outputs.

In cognitive science, human experimentation is combined with formal and computational analyses to understand complex intelligent processes such as language, reasoning, and visual information processing. Such research is beginning to answer age-old questions about the nature of mind and has application in the fields of education, artificial intelligence, human-machine interaction, and in the treatment of cognitive and language disorders. Cognitive science research is focused on psycholinguistics, including sentence and word processing, language acquisition, and aphasia; visual cognition, including reading, imagery, attention, and perception of complex patterns such as faces and objects; and reasoning, including learning, probabilistic reasoning, and the nature and development of concepts. In the field of perception, there is an effort to understand the encoding of color, lightness, form, and depth information by the visual system and the development of these processes in infants. In behavioral neuroscience, research is conducted on neurologically impaired patients in an attempt to understand brain mechanisms underlying normal human sensation, perception, cognition, action, and affect.

Departmental laboratories are well equipped for studies ranging from molecular neurobiology to electrophysiology, neuropsychology, psychophysics, human information processing, and linguistics. In addition, the department maintains a machine shop, an electronics shop, and the Teuber Reading Room. Whitaker College facilities include a VAX 11/780 mainframe computer with numerous terminals, as well as a growing network of SUN 3 computers, Symbolics LISP machines, and numerous laboratory and office microcomputers. The multi-user laboratory of the Center for Cognitive Science provides computational facilities for real-time experimental control, data analysis, modeling, and linguistic analysis. There is an electron microscopy laboratory operated jointly by the Whitaker College and the Department of Biology, and researchers whose investigations involve human subjects have access to MIT's twelve-bed Clinical Research Center. Students and faculty may also use the facilities of other MIT departments and centers.

Undergraduate Offerings

Subjects at the undergraduate level normally begin with 9.00 Introduction to Psychology or 9.62J Introduction to Cognitive Science. More advanced subjects are available in the areas covered by the Department. For all undergraduates, many subjects may be taken to fulfill the Institute Requirement in the Humanities, Arts, and Social Sciences. Students interested in developing strong backgrounds in cognitive science should consider the Bachelor of Science in Cognitive Science.

Psychology

The field of psychology is represented at MIT by an interdisciplinary Program in Psychology in the School of Humanities and Social Science. The Program in Psychology encompasses subjects from the Department of Brain and Cognitive Sciences, the Sloan School of Management, the History Section in the Department of Humanities, the Program in Science, Technology, and Society, and others. It administers a HASS Concentration and Minor in Psychology. For information about the Concentration, contact Professor Alan Hein (E10-208, 253-5759). For information about other aspects of the Program, contact Professor Jeremy Wolfe (E10-137, 253-4875).

The **Minor Program** in Psychology consists of six subjects arranged into three levels of study that provide students breadth in the field as a whole and some depth in one area of specialization. The three levels are as follows:

TIER I: One subject:

9.00 Introduction to Psychology

TIER II: Three subjects, one from *each* of the following areas:

1) Experimental Psychology
2) Personality and Social Psychology
3) Applied Psychology

TIER III: Two subjects from *one* of the following areas:

1) Experimental Psychology
2) Personality and Social Psychology
3) Applied Psychology

For a listing of available subjects in these areas, consult the Undergraduate Psychology Office (E10-008), Psychology Program Coordinator Professor Jeremy Wolfe (E10-137), or the HASS Information Office (14N-408).

Bachelor of Science in Cognitive Science Course IX

Cognitive science is an evolving field of study concerned with human intelligence. Central issues in the discipline include the structure, acquisition, use, and internal representation of human language, the interpretation of sensory experience, the development of formal and informal reasoning skills, the manipulation and storage of information within the nervous system, and the planning and execution of motor activity.

The Bachelor of Science in Cognitive Science prepares students for graduate training in psychology, linguistics, philosophy, or aspects of artificial intelligence (particularly those aspects concerned with vision) as well as for further work in the area of efficient human-machine interaction.

Methods of inquiry in cognitive science are drawn from cognitive and perceptual psychology, computer science and artificial intelligence, linguistics, philosophy of language and mind, neuroscience, and mathematics. The undergraduate program is designed to provide instruction in the relevant aspects of these various disciplines. The program is administered by a committee made up of faculty members from these disciplines who also serve as advisors to majors, helping them select a coherent set of subjects within the requirements, including an independent research project. Members of the committee are available to guide the research.

Bachelor of Science in Cognitive Science Course IX

Degree requirements applicable to the Class entering MIT in September 1986 (Class of 1990) and subsequent Classes:*

General Institute Requirements	17 Subjects
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [3 subjects can be satisfied by subjects in the Departmental Program (for the Field of Concentration)]	8
Science Distribution Requirement	3
Laboratory Requirement	1
TOTAL Subjects	17

PLUS

Departmental Program	Units

Subject names below are followed by credit units and by prerequisites if any (corequisites in italics)

Required Subjects: **78-87**

9.62J Introduction to Cognitive Science, 12

One of the following two subjects:[1]

24.241 Logic I, 12

6.045J Automata, Computability, and Complexity, 12; 18.310**

Four of the following six subjects:

24.900J The Study of Language, 12

9.65 Cognitive Processes, 9

6.001 Structure and Interpretation of Computer Programs, 15

9.01 Neuroscience and Behavior, 12; 9.62J**

9.35 Perceptual Information Processing, 9; 9.62J**

24.119 Minds and Machines, 12

plus

Twelve units of independent research in the senior year (requires prior approval of the advisor): 9.50, 9.91, 9.92, 24.292, or 24.293

Restricted Electives: **48**

A total of at least 48 additional units, to be chosen with approval of the student's faculty advisor, to comprise a coherent program in one of the following areas: 1. Human Information Processing; 2. Language, computational approach; 3. Language, experimental approach; 4. Vision, computational approach; 5. Vision, experimental approach; 6. Motor Control and Robotics; 7. Reasoning; 8. Language Acquisition and Cognitive Development; 9. Philosophy of Mind and Language.

Units in Departmental Program that also satisfy the General Institute Requirements	**(27-36)**
Unrestricted Electives	**75-84**
Total Units Required for the S.B. Degree Beyond the General Institute Requirements	**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1986 are given at the end of the description of the department's undergraduate program.
**Alternate prerequisites are listed in the subject description.

[1] 24.972 also satisfies the requirement.

Bachelor of Science in Cognitive Science Course IX

Degree requirements applicable to Classes that entered MIT prior to September 1986 (through the Class of 1989):

General Institute Requirements	Total Units
Science Requirement	60
Humanities, Arts, and Social Sciences Requirement can be satisfied by subjects in the Departmental Program (for the Field of Concentration), plus appropriate subjects totaling	45
Science Distribution Requirement	36
Laboratory Requirement	12

Departmental Program

Subject names below are followed by credit units and by prerequisites if any (corequisites in italics)

Required Subjects: **78-87**

9.62J Introduction to Cognitive Science, 12

One of the following two subjects:[1]

24.241 Logic I, 12

6.045J Automata, Computability, and Complexity, 12; 18.310*

Four of the following six subjects:

24.900J The Study of Language, 12

9.65 Cognitive Processes, 9

6.001 Structure and Interpretation of Computer Programs, 15

9.01 Neuroscience and Behavior, 12; 9.62J*

9.35 Perceptual Information Processing, 9; 9.62J*

24.119 Minds and Machines, 12

plus

Twelve units of independent research in the senior year (requires prior approval of the advisor): 9.50, 9.91, 9.92, 24.292, or 24.293

Restricted Electives: **48**

A total of 48 additional units, to be chosen with approval of the student's faculty advisor, from lists (provided by the Department) of subjects in: Experimental Cognitive Psychology, Aspects of Natural Language, Neurological Foundations of Cognition, Perception, Natural Computation, and Philosophy of Mind. Normally, the choice will be constrained by the subjects chosen under the Required Subjects above.

Unrestricted Electives	**78-87**
Total Units Required for the S.B. Degree	**360**

*Alternate prerequisites are listed in the subject description.

[1] 24.972 also satisfies the requirement.

Graduate Study

The Department offers programs of study leading to the doctoral degree in Molecular Neurobiology, Systems Neuroscience, Computational Neuroscience, and Cognitive Science. The programs are designed to prepare participants to teach and do original research.

Entrance Requirements for Graduate Degrees

Students should have one year of college-level work in three of the following five areas: physics, chemistry, biology, mathematics, and computer science. Students who do not fulfill these requirements may be considered by the Department on a case-by-case basis.

Doctor of Philosophy

General Institute requirements for the Ph.D. are given in Chapter IV. Formal course work, described below, is intended to prepare the student to pass the general examinations and do original thesis research. The general examinations will be given in May or June of the second year. There is no language requirement for the doctorate.

Specific course requirements vary with the area of specialization. Students in neurobiology, neuroscience, and computation start with an intensive neuroscience core course. The core course covers the molecular and cellular features of neurons, neurophysiology and neuroanatomy, the study of sensory and motor systems, and the principles of neural computation. Further course work will be diversified to give each individual the appropriate background for research in his or her own area. Course work in **Molecular Neurobiology** (organized in collaboration with the Department of Biology) will emphasize the current genetic, molecular, and cellular approaches to biological systems that are necessary to generate advances in neuroscience. Training in **Systems Neuroscience** will cover neuroanatomy, neurophysiology, and neurotransmitter chemistry, concentrating on the major sensory and motor systems in the vertebrate brain. Specific ties to molecular neurobiology or computation may be emphasized, depending upon the research interests of the student. Course work for students in **Computational Neuroscience** is intended to give both an understanding of empirical approaches to the study of the vertebrate brain and a theoretical background for analyzing computational aspects of biological information processing.

Candidates for a degree in **Cognitive Science** take an intensive core course in contemporary cognitive psychology that introduces major theoretical and empirical issues in perception, language, conceptual development, mental representation, memory, and reasoning. Additional course work covers such topics as language processing, language acquisition, cognitive development, natural computation, connectionist models, and visual information processing. Students also participate in advanced seminars and courses outside the Department that are relevant to the individual program of research. The latter may include subjects in linguistics, philosophy, logic, mathematics, or computer science. Competence in statistics in also required.

Graduate students begin research apprenticeship immediately upon arrival, at which time an advisor assignment is made based upon a match of interests. This initial assignment may change as a student's goals become more focused. At the end of the first year, a supervisory committee of two to four faculty members is formed. This committee monitors progress during the early years and, with membership changing as necessary, evolves into the thesis committee. Thesis research normally requires 24-36 months of full-time activity after the qualifying examinations have been passed. It is expected that the research embodied in the Ph.D. dissertation will be original and significant work, publishable in scientific journals.

Assistantships and Fellowships

Financial assistance is available to qualified applicants in the form of traineeships, research assistantships, teaching assistantships, and a limited number of fellowships, subject to availability of funds. Prospective students are encouraged to apply for individual fellowships such as those sponsored by the National Science Foundation, the Howard Hughes Medical Institute, and the Office of Naval Research, to cover all or part of the cost of their education.

Inquiries

Additional information regarding teaching and research programs in the department may be obtained from Jan Ellertsen, Department of Brain and Cognitive Sciences, Room E25-506, MIT, Cambridge, Massachusetts 02139, (617) 253-5741.

Additional Programs

Harvard-MIT Division of Health Sciences and Technology

Harvard University and MIT are engaged in a major collaborative effort, the Harvard-MIT Division of Health Sciences and Technology, designed to focus science and technology on human health needs. In this Division, the complementary resources and strengths of both institutions are being directed to the education of physicians, medical engineers, medical physicists, and other health scientists, and to the effective application of modern science and technology to major health problems.

The Division represents a fusion of the growing interests of MIT and Harvard in developing new patterns of education and research in health and medicine and in more effectively utilizing science and engineering in meeting important health needs. The Division is active in education, research, and development.

The Division offers several educational programs: in Biomedical Sciences leading to the M.D. degree, and in Biomedical Engineering and in Medical Engineering/Medical Physics leading to the Ph.D.

Biomedical Sciences is oriented toward students with a strong interest and background in quantitative science, especially in the biological, physical, engineering, and chemical sciences. Subjects in human biology developed for this curriculum represent joint efforts of life scientists, physicians, physical scientists, and engineers selected from the faculties of both universities. Subjects are presented at Harvard Medical School or at MIT.

The programs of study are formulated to meet the interests and needs of the individual student. The student is encouraged to pursue advanced study in areas of interest that may complement the courses offered in the Division. Such study may be undertaken as part of the curriculum leading to the M.D. degree or may be pursued in a combined M.D.-master's degree or M.D.-Ph.D. program. Students are encouraged to become involved in independent faculty-directed research early in their training. Some students may opt to extend the duration of their medical education to five or more years in order to allocate more time to research. HST students join the students of the regular Harvard Medical School curriculum in the clinical clerkships. HST students are expected to choose a field of concentration in which they spend approximately one half of their elective time. Faculty tutors provide guidance in the choice of subjects and in the pursuit of independent study. Students are expected to present evidence of scholarly work in the form of a thesis based on laboratory research, clinical investigation, critical analysis of a significant medical problem, or other activities approved by the faculty tutors.

The programs of study are designed to develop physicians with a strong quantitative science base, e.g., a cardiologist with knowledge of fluid mechanics and electrophysiology; an internist with experience in molecular biology and biochemistry and qualified to study and treat metabolic disorders; a neurologist acquainted with concepts of computer science and artificial intelligence; an orthopedic surgeon with extensive knowledge of mechanical engineering; a physician-administrator with extensive knowledge of the planning and management of health services.

Approximately 30 students are admitted each year as candidates for the M.D. degree at Harvard Medical School. Financial support is available to qualified HST/MD students through the standard graduate school mechanisms of Research and Teaching Assistantships.

Further details on the Biomedical Sciences Program and application forms may be obtained from the Office of Admission, Harvard Medical School, 25 Shattuck Street, Boston, MA 02115. Applications must be submitted by October 15 of the year prior to desired matriculation.

The doctoral curriculum in **Medical Engineering and Medical Physics** prepares individuals who will be thoroughly grounded in an engineering discipline or in physics, and who will also have extensive knowledge of human biology and clinical medicine. Graduates are well prepared for independent interdisciplinary research at the interface of technology and medicine.

There are four major components to the curriculum: 1) an intensive graduate program in an engineering department or in physics, which includes electives in biomedical engineering subjects[1]; 2) a series of subjects in human biology, taken together with HST/MD candidates[2]; 3) specialized clinical training, which is designed to equip the student conducting effective research in patient-care environments, and to thoroughly understand the process of medical decision-making and the role of technology in health care delivery; and 4) doctoral thesis research on a fundamentally and clinically important problem in medical engineering or medical physics.

Approximately 10 students are admitted each year into the Ph.D. program. Students with undergraduate degrees in engineering or physics must apply for admission **jointly** to a graduate department at MIT or Harvard, and to the HST Division. Students who already possess a master's degree in engineering or physics may apply to the HST Division alone. Applications are due by January 15 of the year of desired matriculation.

The HST Division is committed to educating physicians who will also have a deep understanding of the scientific basis of medicine, and who are equipped for a career of interdisciplinary research. As part of its educational strategy, the Division encourages students to spend time in research during their M.D. curriculum, and a thesis is required for the M.D. degree. Many students, however, desire to obtain more substantial research training than is possible in the standard four-year M.D. curriculum. One existing route for such students is to pursue a formal Ph.D. program in addition to M.D. A second option stretches the duration of the M.D. Program to five or more years in order to permit the inclusion of a major research training component, and leads to the master's degree in Health Sciences and Technology, to be awarded in addition to the M.D. degree.

The general requirements for a master's program at MIT are given in Chapter IV. The course requirements must be in addition to the minimum number of units required for M.D. degree. Subjects may be chosen in scientific, technical, or clinical areas relevant to the student's research area. Thesis research may be conducted at MIT, Harvard, or at Harvard-affiliated teaching hospitals. The completed thesis document must be approved by the thesis supervisor and must be submitted to the HST/MD Graduate Committee. The master's thesis will simultaneously fulfill the thesis requirement for the HST/MD degree.

Although the Master's Degree Program in Health Sciences and Technology is available only for students who are also enrolled in the HST/MD curriculum, the two degrees are not formally linked. Obtaining the M.D. degree is not a prerequisite for the master's degree.

Over 160 faculty members from MIT and Harvard Medical School are associated with the Division. Further information with a complete listing of the faculty and description of all programs, may be obtained from the office of the Directors of the Division, Room E25-519 at MIT, (617) 253-7470. Information on interdepartmental opportunities in biomedical engineering may be found in Chapter VI.

1
The S.M. Degree, including thesis, is required of students associated with departments that normally require the S.M. degree as part of the doctoral program.

2
The subjects HST 011, HST 031, HST 091, HST 101, HST 111, and HST 131J.

Additional Programs

Joint Program in Oceanography and Oceanographic Engineering with the Woods Hole Oceanographic Institution

MIT and the Woods Hole Oceanographic Institution (WHOI) on Cape Cod offer joint doctoral degrees in oceanography and both doctoral and professional degrees in oceanographic engineering. Graduate study in oceanography encompasses virtually all of the basic sciences as they apply to the marine environment: physics, chemistry, geology, geophysics, and biology. Oceanographic engineering allows for concentration in the major engineering fields of civil, mechanical, electrical, and chemical, as well as materials science and ocean engineering. The graduate programs are administered by joint MIT/WHOI committees drawn from the faculty and staff of both institutions. Students accepted to the Joint Program have access to the extensive intellectual and physical resources available for advanced study at both Woods Hole and MIT.

The Joint Program involves several departments at MIT — Earth, Atmospheric, and Planetary Sciences and Biology in the School of Science; and Chemical Engineering, Civil Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, and Ocean Engineering in the School of Engineering. Financial aid, offered as research assistantships to most entering graduate students, is sufficient to cover tuition and fees and provide a stipend. Upon admission, students register in the appropriate MIT department and at WHOI simultaneously, and are assigned academic advisors at each institution. Because the Joint Program is not affiliated with any one particular MIT department, it is important that students who wish to be considered for the Joint Program indicate this intent on the front of their applications.

Research at WHOI is devoted to using the basic sciences and engineering to gain a better understanding of the marine environment. Some 200 scientists and technicians and a support staff of about 600 work in five large laboratories and smaller facilities located in Woods Hole and on the nearby Quisset Campus. Another 75 people operate three research vessels ranging from 177 to 245 feet in length, the deep-diving submersible ALVIN, and a small coastal vessel. Computer services are provided within WHOI and include links to other institutions. A microwave link between MIT and Woods Hole provides interactive video-voice transmission for classes and a high-speed data link for research. The library facilities are shared with the Marine Biological Laboratory and are supplemented by collections of the Northeast Fisheries Center of the National Marine Fisheries Service and the US Geological Survey's Office of Marine Resources Branch of Atlantic Geology, all located in Woods Hole. The village is situated on the southwest corner of Cape Cod, about 80 miles from Boston.

Subjects, seminars, and opportunities for research participation are offered at both MIT and WHOI. Place of residence is determined by the student's selected program of study and research interests, and transportation is provided between institutions. Students also have the opportunity to participate in oceanographic cruises during graduate study.

The faculty of MIT, together with the WHOI staff, offer a wide variety of formal and informal courses in various aspects of oceanography and areas directly applicable to ocean science and engineering; both faculties are equally involved in all levels of instruction. The courses are supplemented by numerous seminars, directed studies, and cross-registration privileges with Harvard, Brown, and the Boston University Marine Program. Most courses are offered on an alternate year program; complete listings can be found in the course descriptions of each individual department.

Physical Oceanography

Physical oceanography is the study of the physics of the ocean. Its central goal is to describe and explain the complex motions of the ocean. Principal research areas include general circulation, air-sea interaction, shelf dynamics, mesoscale processes, and small-scale processes. The Department of Earth, Atmospheric, and Planetary Sciences offers programs in physical oceanography with WHOI, which lead to the Doctor of Science or Doctor of Philosophy degree.

Chemical Oceanography

Chemical oceanographers study the chemical composition of the marine environment and the processes that have produced the present composition of sea water and sediments. Principal research areas include water column geochemistry, sedimentary geochemistry, sea-water-basalt interactions, and atmospheric chemistry. The Departments of Earth, Atmospheric, and Planetary Sciences and Civil Engineering offer programs with WHOI in chemical oceanography and marine geochemistry. These programs lead to the degree of Doctor of Science or Doctor of Philosophy.

Marine Geology and Geophysics

The goal of Marine Geology and Geophysics is to understand the physical and chemical processes that determine the structure and evolution of the ocean basins and their margins. Research is being conducted in a wide range of specialties including micropaleontology, paleoceanography, petrology and volcanic processes, seismology, gravity, magnetics, heat flow, sediment dynamics, and isotope geology. The Department of Earth, Atmospheric, and Planetary Sciences at MIT offers programs with WHOI in marine geology and geophysics which lead to the Doctor of Science or Doctor of Philosophy.

Biological Oceanography

Biological oceanography seeks to describe the biological processes which are active in the marine and bordering environments. The research of biological oceanographers is diverse, ranging from ecology and systematics to biochemistry and physiology. The programs in biological oceanography are coordinated by the Department of Biology and WHOI, and may involve research in other MIT departments such as Civil Engineering. The programs lead to the Doctor of Science or Doctor of Philosophy.

Oceanographic Engineering

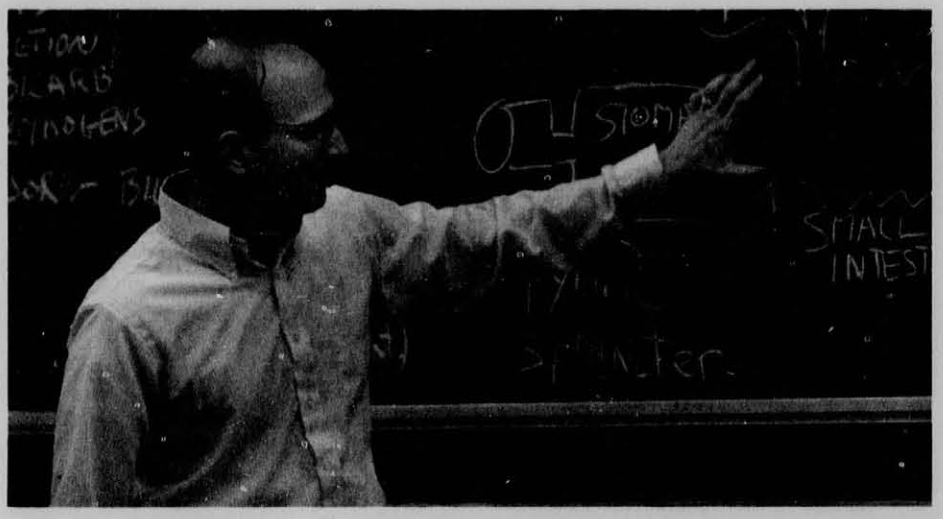
Oceanographic engineering involves the application of physics and the engineering sciences to the study of oceanic processes and the design of instruments, systems, and structures required to observe, measure, and work in the ocean. The Departments of Chemical Engineering, Civil Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, and Ocean Engineering offer joint programs with WHOI in oceanographic engineering. The programs lead to the Engineer, Doctor of Science, or Doctor of Philosophy degree.

Inquiries

Application for admission to the Joint Program should be made on the MIT Graduate Application Form, which may be obtained from the Director of Admissions at MIT or from the Education Office at WHOI. Requests for further information may be addressed to the Dean of Graduate Studies, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, (617) 548-1400, x2200; or to the MIT Joint Program Office, Room 5-206, Cambridge, Massachusetts 02139, (617) 253-7544.

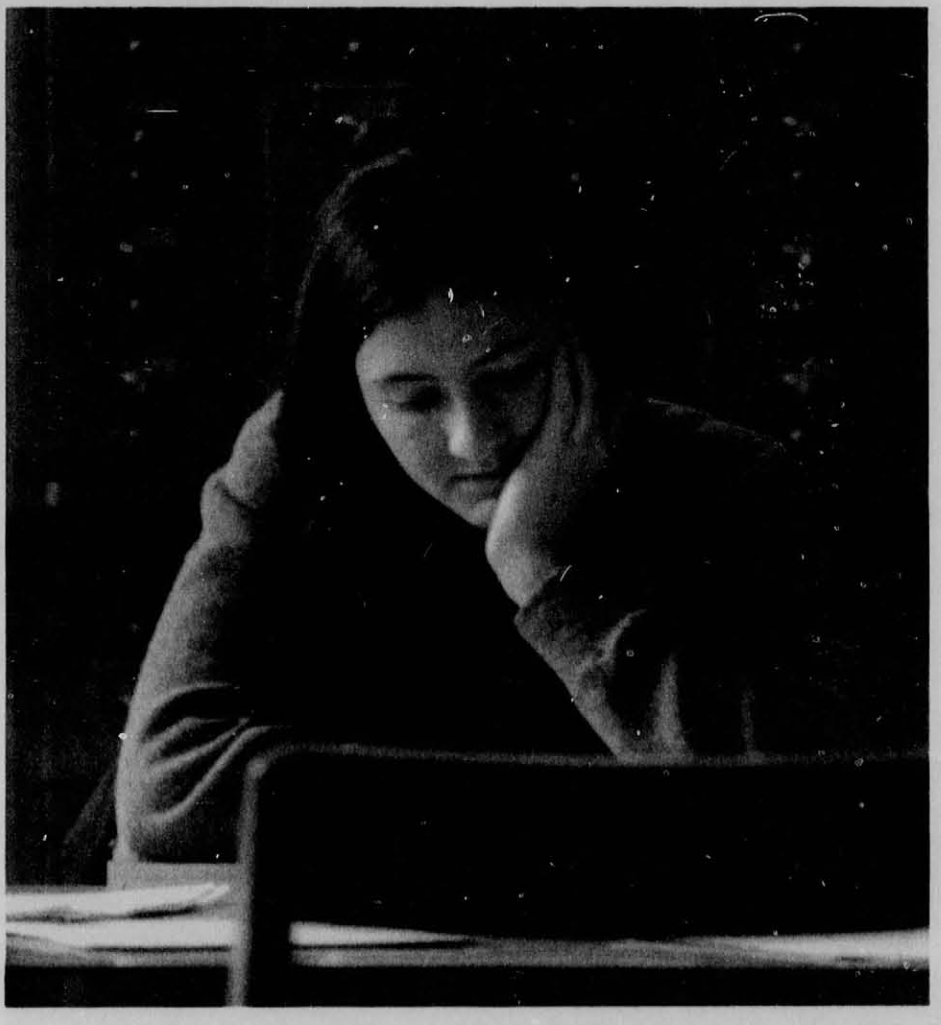


Descriptions of Subjects









Explanatory Notes

The descriptions in this chapter are subject to change. The final list of subjects to be offered in 1988-89 will be published with the class schedules booklet prior to the beginning of each term.

The information below the **number and name of the subject** is as follows:

The number(s) of **prerequisite subjects,** if any. Numbers in italics indicate subjects that may be taken simultaneously with the subject described. Prerequisites may be waived by the instructor in charge for particularly well-qualified students.

The **year classification (and term)** in which the subject is normally scheduled. "U" is an undergraduate subject, and "G" is a subject primarily for graduate students. 1, 2, J, and S represent fall, spring, January, and summer terms, respectively.

SD or LAB or HASS-D/HUM-D indicates that the subject is on the approved list for Science Distribution; Laboratory; or Humanities, Arts, and Social Sciences Distribution credit.

HASS indicates subjects outside the School of Humanities and Social Science that can be used to satisfy the Humanities, Arts, and Social Sciences Requirement (other than HASS-D/HUM-D subjects).

[P/F] indicates subjects that are offered on a pass/fail basis only.

The **year offered** comment states "Next offered 1989-90" or "Not to be offered 1989-90." There is no comment if it is offered both in 1988-89 and 1989-90.

The **time distribution of the subject,** showing in sequence the units allotted to: recitation and lecture; laboratory, design, or fieldwork; and preparation. Each unit represents 15 hours of work. The total unit credit for a subject is obtained by adding together all the units shown. One unit of lecture or recitation credit is equivalent to one semester hour. "Arr." indicates that time units are specially arranged.

The **name of the instructor(s)** in charge, as known at press time.

(New) below the subject number and title indicates a new offering.

(Revised Unit) or **(Revised Content)** below the subject number and title indicates a change from the previous catalogue.

A **renumbered subject** is so indicated in parentheses below the current number.

J at the end of a subject number indicates that this subject is offered jointly by more than one department. The subject numbers of the other departments are indicated (Same subject as ————).

(A) following the name of a subject indicates that it is an approved subject for a graduate degree and is given primarily for graduate students.

All subjects open only to special groups are so noted at the end of the description of the subject.

Department (by School or College)	**Course Number**
Architecture	4
Urban Studies and Planning	11
Aeronautics and Astronautics	16
Chemical Engineering	10
Civil Engineering	1
Electrical Engineering and Computer Science	6
Materials Science and Engineering	3
Mechanical Engineering	2
Nuclear Engineering	22
Ocean Engineering	13
Economics	14
Humanities	21
Linguistics and Philosophy	24
Political Science	17
Management	15
Biology	7
Chemistry	5
Earth, Atmospheric, and Planetary Sciences	12
Mathematics	18
Physics	8
Program in Applied Biological Sciences	20
Brain and Cognitive Sciences	9

Program	**Letter Code**
Health Sciences and Technology	HST
Special Programs	SP
Science, Technology, and Society	STS
Engineering School-Wide Electives	SWE
Technology and Policy	TPP
Aerospace Studies	AS
Military Science	MS
Naval Science	NS

Course 1 Civil Engineering

Fundamentals

1.UR Research in Civil Engineering

Prereq.: —
U (1, 2) [P/F]
Arr.

Individual research or laboratory study under faculty supervision. Also, opportunities in ongoing research program. Limited number of funded traineeships available.
Information: H. F. Hemond.

1.00 Introduction to Computers and Engineering Problem Solving

Prereq.: —
U (1, 2) SD
3-1-8

Fundamental computational algorithms for engineering and scientific applications. The C programming language and UNIX are presented. Weekly programming problems cover numerical analysis, graphics, data structures, searching, sorting, matrix methods, and simulation. Emphasis on developing techniques for software design. Programming background helpful.
J. H. Slater, N. H. M. Wilson

1.01J Engineering Aspects of Economic Analysis

(Same subject as 14.014J)
Prereq.: —
U (2) HASS
3-2-7

Same subject as 14.01, with additional recitation sections scheduled for Civil Engineering majors to relate the concepts covered in lectures to engineering problems and applications. Credit is not given for both 14.01 and 14.014J or 1.01J. Consult K. D. Stolzenbach.

1.02 Optimal Design of Engineering Systems
(Revised Content)

Prereq.: 1.00 or equivalent
U (1)
3-1-8

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
H. N. Psaraftis, Y. Sheffi, R. C. Larson

1.03 Introduction to Probability and Statistics for Engineers

Prereq.: *18.03*
U (1)
3-2-7

Elements of probability and statistics with emphasis on engineering applications. Probability topics include analysis of Bernoulli Events, common distributions including exponential, Poisson, normal, lognormal, and extreme value. Statistics include point and interval estimation and hypothesis test.
F. E. Perkins

1.04 Behavior of Physical Systems I

Prereq.: 8.01, 18.02
U (1) SD
3-2-7

Applies statics, geometric compatibility, and force-deformation relations in analysis of simple determinate and indeterminate structures. Reactions, internal forces, and deflections for beams and trusses. Introduces stress-strain behavior of construction materials, stress in two dimensions (Mohr's circle), and stability and buckling. Exercises using computers.
L. J. Gibson

1.05 Behavior of Physical Systems II

Prereq.: 8.01, *18.03*
U (2)
3-2-7

Applies basic physical principles to the engineering analysis of solid and fluid systems. Includes static equilibrium of fluids, conservation of mass and momentum of moving fluids, thermodynamic properties, first and second laws of thermodynamics. Applications to fluid forces on structures, flow in conduits and channels, state changes, mechanical and thermodynamic energy cycles.
K. D. Stolzenbach

1.06 Probabilistic Models in Engineering
(Revised Content)

Prereq.: 1.03 or 6.041 or 18.05
U (2)
3-2-7

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. R. Odoni, R. C. Larson, H. N. Psaraftis

1.07 Engineering Applications of Artificial Intelligence

Prereq.: 6.034 or Permission of Instructor
U (2)
3-0-9

Applications of artificial intelligence techniques to engineering problem solving are addressed. Topics include basic search techniques, knowldege-based systems, natural language processing, and robotics.
D. Sriram

1.08 Design of Automated and Robotic Systems

Prereq.: —
U (1)
3-0-9

Application of both software and hardware aspects of automation and robotics to streamlining the design and construction process. Data acquisition and processing, control theory and its applications to automation of construction and manufacturing processes. Students required to design an automated systems for a term project.
A. Slocum

For additional undergraduate introductory subjects, see: 1.30, 1.40, 1.50, 1.60, 1.70, 1.80.

Undergraduate Laboratory Subjects

1.101 Decision Analysis Laboratory

Prereq.: 1.00 or UNIX capability
U (2) LAB
3-4-5

Explores the nature and existence of utility, the basic model of how people respond to and choose between alternatives. Students proceed through introductory experiments to a major project involving interviews and addressing a key issue of human perception of risk and value. Brief lectures present the necessary theory and psychometric techniques. Special UNIX programs are used to reduce and plot data, and to test theoretical hypotheses. The implications for decision analysis and engineering design are stressed.
R. de Neufville

1.102 Transportation Laboratory

Prereq.: —
U (2) LAB
0-3-3

Laboratory experience with the properties of transportation systems. Students formulate an experiment based upon readings and discussions of current transportation problems. Emphasis on formulation of hypotheses about properties and effects of different types of transportation systems; planning of experiments and data collection in the field to test these hypotheses, analysis of results, and development of recommendations for changes in transport systems plans and policies.
Y. Sheffi

1.105J Structural Engineering Laboratory

(Same subject as 4.315J)
Prereq.: —
U (1) LAB
0-3-3

Introduces students to properties of structural materials and behavior of simple structural elements and systems through a series of experiments. Several laboratory projects involve the student as both the designer and fabricator of a structure. Information: J. J. Connor, Jr.

1.106 Laboratory Projects in Environmental Fluid Mechanics

Prereq.: —
U (1) LAB
0-3-3

The measurement, analysis, and modeling of physical parameters such as velocity, salinity, temperature, dissolved solids, etc., in natural water bodies. Application of these techniques in the context of laboratory experiments and one or more field studies. Certain experiments complement lectures in 1.60, but concurrent registration in 1.60 or previous fluid mechanics experience is not required.
E. E. Adams

1.107 Aquatic Chemistry and Biology Laboratory

Prereq.: 5.40 or 5.11
U (2) LAB
2-6-4

Field sampling and laboratory analysis techniques for determining chemical (e.g., salinity, O2, nutrients, haloforms, petroleum hydrocarbons) and biological (e.g., coliforms, chlorophyll) parameters in aquatic samples. Both wet-chemical and instrumental (e.g., atomic absorption spectrometry and gas chromatography) methods. Three field trips are taken to acquire "real world" samples for analysis and interpretation of the data in terms of water quality and the processes affecting it.
P. M. Gschwend, S. W. Chisholm

General Methods and Concepts

Listed below are a number of subjects concerned with general methods and concepts rather than specific applications areas. Topics include:

- **Information Systems and Computational Methods**
- **Analytical Mechanics**
- **Engineering Systems, Economics, and Management**
- **Engineering Risk Assessment and Probabilistic Analysis**
- **Institutions and Public Policy**

Subjects under these headings are of interest to students from a variety of backgrounds, both from within and outside the Department. Subjects more oriented to applications based on these methodologies are noted at the end of each section.

Information Systems and Computational Methods

1.12 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

1.121 Numerical Modeling of Physical Systems (A) (Revised Unit)

Prereq.: 18.03
G (1)
3-0-9

Survey of numerical methods for ordinary and partial differential equations. Emphasis on finite difference and weighted residual methods. Includes review of linear algebra; introduction to partial differential equations; finite difference approximations; consistency, stability, and convergence; Fourier analysis; finite element methods. Examines both steady and transient equations describing physical systems of interest. Development of computer programs is emphasized.
M. A. Celia

1.122 Finite Element and Boundary Element Methods (A) (Revised Unit)

Prereq.: 1.51
G (2)
3-0-9

Finite element and boundary element methods for the analysis of continuous media. In-depth discussion of variational principles, weighted residual methods, penalty methods, integration techniques. Application to two- and three-dimensional domains with examples pertaining to stress analysis, thermal analysis, and harmonic problems. Use of commercial software for homework assignments, with the primary emphasis on developing expertise in modeling and interpretation of numerical output.
J. J. Connor, Jr.

1.123 Building Knowledge-Based Systems for Engineering Problem Solving (A) (Revised Unit)

Prereq.: Permission of Instructor
G (1, 2)
3-0-6

Approaches and existing software tools for building knowledge-based expert systems are discussed and illustrated with examples drawn from Civil Engineering. Students are expected to carry out a project involving the construction of a knowledge-based system for a specific problem.
D. Sriram

For additional related subjects, see: 1.204J, 1.368, 1.70.

Analytical Mechanics

1.13 Design for Construction Automation (A)

Prereq.: 1.08
G (2)
3-0-9

Covers the fundamentals of computer-controlled machinery design (electronic and mechanical systems). The theme of the course is design of integrated CNC machine systems to automated construction processes. Grading is based on participation in solving a "real world" project. Students are required to design a complete computer controlled machine.
A. Slocum

1.131 Analytical Methods in Physical Systems

Prereq.: 18.03
G (1) **Next offered 1989-90**
4-0-8

A utilitarian survey of elementary and intermediate analytical techniques, and their applications in physical systems. Linear partial differential equations. Separation of variables. Green's functions. Complex variables and contour integration. Integral transforms. Formulation and solution of problems in seepage flows, statics and vibration of elastic structures, soil consolidation, and diffusion of energy or matter. Introduction to perturbation methods. Open to advanced undergraduates also.
C. C. Mei

1.132 Advanced Engineering Mechanics (A)

Prereq.: 1.51
G (1)
3-0-6

Survey of the mechanics of solids and structures, with particular emphasis on structural engineering applications. Includes fundamentals of continuum mechanics, theory of elasticity, and theory of thin plates and shells. Provides a sound background for engineering analysis and appreciation of structural behavior.
M. M. Baligh, V. C. Li

1.134 Nonlinear Constitutive Theories of Engineering Materials (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Predictive mechanical models for solids and structures are based on constitutive theories that characterize the mechanical behavior of materials. Fundamental theories describing the nonlinear continuum behavior of engineering materials are presented, emphasizing their numerical implementation and application to contemporary materials. Topics include nonlinear elasticity; plasticity; viscoelasticity, creep, and viscoplasticity; damage mechanics; large deformations. See also 2.073 and 16.24.
S. Shyam Sunder

1.135 Dynamics of Structures and Soils (A)

Prereq.: 1.30, 1.51
G (2)
3-0-6

Basic principles of dynamics of linear systems, as applied to analysis of structures, soils, and soil-structure interaction. Single and multiple degree of freedom systems, including modal analysis; excitation by applied forces and by ground motions. Wave propagation in one and two dimensions. Dynamics of a mass on an elastic half-space.
E. Kausel, R. V. D. Whitman

1.137 Studies in Analytical Mechanics (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Individual study of advanced subject material under staff supervision.
Information: J. J. Connor, Jr.

For additional related subjects see: 1.351, 1.382, 1.541, 1.542, 1.56J, 1.571, 1.572, 1.63, 1.64, 1.691.

Engineering Systems, Economics, and Management

1.146 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. de Neufville, J. P. Clark

1.148J Economics of Project Evaluation (A)

(Same subject as 14.111J)
Prereq.: 14.03
G (2)
3-0-6

See description under subject 14.111J.
J. Rothenberg

1.15 Computer Applications in Statistics

Prereq.: 1.00, 1.03 or equivalent
U (2)
2-2-8

Computer application of statistical methods for empirical analysis. Includes sampling theory, experimental design, explanatory data analysis, statistical inference, hypothesis testing, and regression analysis. Application of sample design, data collection, model estimation, parameter estimation, and reporting to four case studies. Data collection in both real world and laboratory settings. Information: D. Marks

For additional related subjects see: 1.202J, 1.203J, 1.207, 1.281, 1.283J, 1.70, 1.731. Subjects dealing with management of engineering systems are: 1.259, 1.40-1.485J, 1.78.

Engineering Risk Assessment and Probabilistic Analysis

1.151 Risk Assessment in Engineering I (A)

Prereq.: —
G (1)
3-0-6

Quantitative analysis of uncertainty in planning, design, construction, and operation of engineered facilities. Interprets fundamentals of probability, random processes, statistics, and decision analysis in the context of engineering applications, in particular, description of variability of loads and environmental conditions, material properties, performance prediction, system reliability analysis, and risk-based decision analysis.
D. Veneziano

1.152 Risk Assessment in Engineering II (A)

Prereq.: 1.151
G (2)
3-0-6

Advanced probabilistic modeling and statistical analysis of spatially and temporally distributed data. Nonparametric and exploratory analysis of multivariate data including regression and contingency tables, analysis of patterns of points, statistical analysis of data from linear, Markov, and Gaussian processes. Each topic includes probabilistic modeling, statistical analysis techniques, and example applications from various areas of engineering and science.
D. Veneziano

1.155 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

For additional related subjects, see: 1.203J, 1.711, 1.712, 1.732.

Institutions and Public Policy

1.165 Introduction to Technology and Law

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. D. Nyhart

For additional related subjects, see: 1.254J, 1.78, 1.811J, 1.812J.

Transportation

1.201J Transportation Systems Analysis (A)

(Same subject as CTS 100J)
Prereq.: Permission of Instructor
G (1)
3-0-6

Introduces the analysis of passenger and freight transportation systems. Deterministic and stochastic models of system performance. Determinants of demand for transportation: travel behavior. Analyzes transportation networks, including prediction of flow patterns and service quality. Evaluates impacts and design of transportation services and facilities. Introduction to simulation, queuing, inventory theory, logistics analysis, and other methods. Considers transportation industry structure.
J. Sussman

1.202J Demand Modeling (A)

(Same subject as CTS 150J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Analysis and forecasting of demand for facilities and services. Emphasis on collection and analysis of survey data. Review elements of probability, sampling, and statistical methods. Includes alternative sample designs and data collection methods, matrix-entry estimation methods, linear regression analysis, discrete choice methods, estimation and testing of disaggregate and aggregate models, aggregate forecasting methods and simulation. Illustrated with applications from the fields of transportation, housing, telecommunications, and marketing. Information: Y. Sheffi

1.203J Logistical and Transportation Planning Methods (A)

(Same subject as 6.281J, 11.526J, 13.665J, 15.078J, 16.76J)
Prereq.: 6.431, 15.075
G (1)
3-0-9

Quantitative techniques of operations research with emphasis on applications in transportation systems analysis (urban, air, ocean, highway, pickup and delivery systems) and in the planning and design of logistically oriented urban service systems (e.g., fire and police departments, emergency medical services, emergency repair services). Unified study of functions of random variables, geometrical probability, multi-server queuing theory, spatial location theory, network analysis and graph theory, and relevant methods of simulation. Computer exercises, discussion of implementation difficulties.
A. I. Barnett, R. C. Larson, A. R. Odoni, H. N. Psaraftis

1.204 Computer Algorithms in Transportation (A) (Revised Unit)

Prereq.: 1.00 or 16.008; 1.02
G (1)
3-0-9

Teaches software development and analytical techniques for transportation systems. Structured programming, data structures, systems analysis and design, and user interfaces. Case studies using operations research techniques for problems in transportation networks, vehicle routing and scheduling, crew scheduling, facility location, and operations management. Extensive micro- and mini-computer assignments.
H. Koutsopoulos

1.205 Advanced Demand Modeling (A)

Prereq.: 1.202J or CTS 150J
G (1) **Next offered 1989-90**
3-0-6

Theories and applications of behavior models. Includes: linear and nonlinear latent variable models, multidimensional probabilistic choice models, survey design, statistical estimation techniques with multiple data sources, model transferability, estimation and forecasting with very large choice sets, joint discrete and continuous models, dynamical models. Issues in model specification, including use of stated preference data, and analysis of complex choices. Term paper required.
M. E. Ben-Akiva

1.207 Transportation Networks Equilibrium Analysis (A)

Prereq.: 1.02, 1.03
G (1) **Not to be offered 1989-90**
3-0-9

Analytical and algorithmic approaches to the formulation and solution of transportation network equilibrium assignment problems. Topics: mathematical programming formulation of user and stochastic user equilibrium problems; combined modal split, distribution, and assignment formulation; implementation of solution algorithms; applications of discrete choice models. Alternate years.
Y. Sheffi, H. Koutsopoulos

1.208J Transportation and Logistics Analysis (A)

(Same subject as 15.770J)
Prereq.: Permission of Instructor
G (2)
3-0-6

Introduction to inventory theory. Analysis of tradeoffs between transportation and inventory cost. Routing and scheduling with inventory considerations. Distribution network design and carrier network design. Optimization of carrier networks with emphasis on truck and rail networks. Integration of carrier and shipper perspective in system models.
Y. Sheffi, S. C. Graves

1.22 Transportation Infrastructure Systems (A)

Prereq.: Permission of Instructor
G (1)
3-3-6

Integrated treatment of analytical methods and new technologies for design, construction, management, operation, and maintenance of transportation facilities throughout their use. Emphasis on a systems approach using computer models. Case studies are used to demonstrate the complex interactions in managing transportation infrastructure.
Information: Y. Sheffi

1.231J Planning and Design of Airport Systems (A)

(Same subject as 16.781J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

Equal emphasis on current practice and advanced concepts. Airport location and planning with full consideration of economic, environmental, and other impacts. Demand prediction, determination of the capacity of the airfield, estimation of levels of congestion. Design of terminals. Role of airports in the aviation and transportation system. Airport access problems. Optimal configuration of air transport networks and implications for airport development. Economics of the airport. Financing and institutional aspects. Special attention to international practice and developments. Alternate years.
R. de Neufville, A. R. Odoni

1.233J Seminar in Air Transportation Analysis and Planning

(Same subject as 16.704J)
Prereq: —
G (1)
1-0-5

See description under subject 16.704J.
A. R. Odoni, C. O. Cary

1.242 Highway, Systems Analysis, and Technology (A)

Prereq.: 1.22 or Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Integrated treatment of technical and economic aspects in highway design, construction, maintenance, and operation. Basic characteristics of roads, traffic flows, and the process of highway project development. Geometric design standards, speeds, capacities, accidents, and construction costs. Introduction to integrated computer-aided highway design. Maintenance and rehabilitation, including requirements, costs, impacts, and policy optimization. Data collection, analysis methods, and management options in traffic operations.
M. E. Ben-Akiva, T. F. Humphrey

1.252J Urban Transportation Planning (A)

(Same subject as 11.380J)
Prereq.: —
G (1)
3-0-6

See description under subject 11.380J.
R. A. Gakenheimer

1.254J Infrastructure in Third-World Countries (A)

(Same subject as 11.469J)
Prereq.: —
G (1)
3-0-9

See description under 11.469J.
R. A. Gakenheimer

1.255J Politics, Technology, and Development in the Middle East (A)

(Same subject as 4.715J, 11.488J, 17.558J, 21.485J, STS 509J)
Prereq.: —
G (1)
3-0-9

See description under subject 17.558J.
N. Choucri, F. Moavenzadeh, R. Lewcock, K. Keniston

1.256J Technology, Business, and Public Policy in the Middle East (A)

(Same subject as 4.716J, 11.489J, 17.560J)
Prereq.: —
G (2)
3-0-9

See description under subject 17.560J.
N. Choucri, F. Moavenzadeh, W. Porter, L. Trilling, E. Westney

1.258 Public Transportation (A) (Revised Unit)

Prereq.: 1.201J or Permission of Instructor
G (2)
3-0-9

Evolution and role of urban public transportation modes, systems, and services, including bus and rail. Description of technological characteristics and their impacts on capacity, service quality, and cost. Current practice and new methods for performance monitoring, route design, vehicle and crew scheduling. Effect of pricing policy and service quality on ridership. Methods for estimating costs associated with proposed service changes. Management of transit systems including strategic planning, labor, maintenance, financing, and marketing.
N. H. M. Wilson

1.27 Studies in Transportation Engineering (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Individual advanced study of a topic in transportation systems, selected with the approval of the instructor. Information: Y. Sheffi.

1.271 Research Seminar in Transportation

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

Research seminar for graduate students in transportation. Discussion of current research at various stages of development, including problem definition, literature review, methodology, and evaluation of results. Intended for advanced doctoral students and for students preparing for the general examination.
J. Sussman

1.281 Transportation Economics (A)

Prereq.: 14.01 or 1.01J
G (1)
3-0-6

Theory and behavior of transportation markets: urban and intercity, passenger and freight, estimation and application of production, cost, and demand functions. Evaluation of governmental transportation policies: economic regulation, infrastructure investments, pricing, and financing: cost-benefit analysis, and impacts upon economic efficiency.
G. McCullough

1.283J Spatial Economics, Urban Markets, and Public Policy (A)

(Same subject as 11.410J, 14.573J)
Prereq.: 14.03
G (1)
3-0-9

See description under subject 11.410J.
W. C. Wheaton, J. Rothenberg

1.286 Freight Transportation Management (A) (Revised Unit)

Prereq.: 1.201J, 1.03
G (2)
3-0-9

Methods for analysis of freight systems, with emphasis on rail and motor carrier operations and management of carrier assets. Study of competitive transportation companies and the environment in which they operate. Market issues, organizational structure, information systems, and decisionmaking processes for fleet management, facility operations, maintenance, and operations/service planning. Case studies illustrate effects of regulation, technology, labor relations, and competition on carrier strategies.
C. D. Martland

1.298 Research in Transportation

Prereq.: —
G (1, 2, S) [P/F]
Arr.

For research assistants in transportation, when assigned research is not used for thesis, but is approved for academic credit. Credits for this subject may not be used for any degree granted by Course I.
Information: Y. Sheffi.

1.299 Teaching in Transportation

Prereq.: —
G (1, 2) [P/F]
Arr.

For teaching assistants, in recognition of the educational value derived from satisfactory performance of assigned duties, and for other qualified students interested in teaching in this area as a career. Laboratory, tutorial, or classroom teaching under supervision of a faculty member. Credits for this subject may not be used for any degree granted by Course I. Information: Y. Sheffi.

Constructed Facilities

Geotechnical Engineering

1.30 Soil Mechanics

Prereq.: 1.04
U (1)
3-1-8

Fundamental principles of soil behavior. Composition and structure of soils; phase relationships and unit weights; classification systems. Influence of pore pressure on strength and compressibility; effective stress, effect of flowing water on stability. Drained and undrained strength. Theory of consolidation. Principles of limit equilibrium analysis for soil masses. Methods for estimating soil deformations. Lectures supplemented by a laboratory and interactive computer-aided design projects.
M. M. Baligh

1.32 Introduction to Engineering Geology

Prereq.: —
U (2) SD
3-3-6

Basic principles of physical geology, emphasizing topics pertinent to civil engineering, and a brief overview on mineral resources. Identification of minerals; igneous, metamorphic, and sedimentary rocks. Alluvial, glacial, eolian, lacustrine, marine, and colluvial sediments. Weathering. Rock defects. Earthquakes. Air photos and geologic maps. Field trips.
H. H. Einstein

1.322 Soil Behavior (A)

Prereq.: 1.361
G (2)
3-1-5

Detailed study of soil properties with emphasis on interpretation of field and laboratory test data for use in practice. Includes: consolidation and secondary compression; basic strength principles; stress-strain strength behavior of clays, emphasizing effects of sample disturbance, anisotropy and strain rate; strength and compression of granular soils; engineering properties of compacted soils. Some knowledge of field and laboratory testing assumed; 1.37 desirable.
C. C. Ladd

1.331 Soil Dynamics (A)

Prereq.: 1.135
G (2)
3-0-6

Stress-strain behavior during transient and repeated loadings, relation to wave velocity. Strength degradation and liquefaction. Analysis of machine foundations; effect of soils upon seismic motions; earth dams and retaining walls during earthquakes; foundations for offshore structures; other selected applications. Alternate years.
R. V. D. Whitman

1.351 Theoretical Soil Mechanics (A)

Prereq.: 1.30
G (1)
3-0-6

Discusses elementary theories important in soil mechanics. Theories of elastic half-space and elastic layers. Applications of elastic theories, especially to settlement problems. Use of limit analyses for active and passive stresses, bearing capacity, and slope stability. Theory of consolidation for one-dimensional problems and introduction to three-dimensional consolidation. Mathematics, construction, and interpretation of flow nets. Introduction to finite element methods and their use.
S. Shyam Sunder

1.361 Advanced Soil Mechanics and Engineering (A) (Revised Unit)

Prereq.: 1.30
G (1)
3-0-9

Consideration of the following fundamentals of soil mechanics: the nature of soil; the effective stress principle; permeability and seepage; stress-strain-strength behavior of cohesionless and cohesive soil; lateral earth stresses; bearing capacity and slope stability; consolidation theory; settlement analyses.
C. C. Ladd

1.364 Foundation Engineering (A)

Prereq.: 1.361 or 1.366
G (1)
3-0-6

Types of foundation systems and design criteria. Design of shallow foundations (footings and rafts), and deep foundations (piles and caissons). Construction methods, problems and effects on nearby structures. Special topics and case studies.
R. V. D. Whitman

1.366 Geotechnical Engineering (A)

Prereq.: 1.30
G (1)
3-0-6

Identification, presentation, and illustration of principles of soil mechanics. Considers the following topics: the nature of soil; the effective stress principle; permeability and seepage; stress-strain-strength behavior of soil; lateral earth stresses. Applies principles to stability and deformation problems. Restricted to graduate students not specializing in Geotechnical Engineering. Same lectures as for 1.361.
C. C. Ladd

1.37 Geotechnical Measurements and Exploration (A)

Prereq.: 1.30
G (1)
2-4-3

Application of testing principles to the measurement of fundamental aspects of soil behavior from classification to engineering properties. Emphasis on rigorous techniques to measure mechanical behavior under various boundary conditions. Exposure to error estimation, research devices, geotechnical field exploration, and *in situ* testing. Experiments include data analysis, evaluation, and presentation.
J. T. Germaine

1.38 Engineering Geology (A)

Prereq.: 1.30, 1.32
G (2)
3-0-6

Effect of geologic features on constructed facilities. Geologic aspects of subsurface exploration. Interaction between man-made structures and the geologic environment. Emphasizes sediment engineering geology with an overview of hard-rock engineering geology. Alternate years.
H. H. Einstein

1.381 Rock Mechanics I (A)

Prereq.: 1.30, 1.32; or 12.01
G (1) **Next offered 1989-90**
3-0-6

Introduces geologic and theoretical aspects of rock mechanics: exploration; geologic and engineering classification; laboratory and field testing; strength, deformability, and permeability of intact rock and rock masses. Application of geologic and theoretical principles to the solution of basic rock engineering problems. Alternate years.
H. H. Einstein

1.382 Rock Mechanics II (A)

Prereq.: 1.381 G (2)
Next offered 1989-90
3-0-6

Advanced treatment of theoretical and experimental aspects of rock mechanics: fracture mechanics, mechanics of discontinuities, rock dynamics. Rock engineering involving advanced analytical and design aspects of rock slopes, foundations on rock, underground openings, and blasting of rock. Alternate years.
H. H. Einstein

1.383 Underground Construction (A)

Prereq.: 1.361, 1.381
G (1)
3-0-6

Familiarization with the most important aspects of planning, design, and construction of underground openings in soft ground and rock. Detailed engineering analysis and design. Major aspects of construction techniques and construction planning. General planning and economic problems. Alternate years.
H. H. Einstein

1.39 Studies in Geotechnical Engineering (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

For graduate students desiring further individual study of special topics.
Information: J. J. Connor, Jr.

Construction Engineering and Management

1.40 Project Management

Prereq.: 1.30, 1.50
U (2)
3-2-7

Overview of construction industry, its organizations and interactions. Project and construction management methodologies presented for project and company planning, control, and decision making. Includes scheduling, accounting, estimating, resource planning, organization structuring used throughout all project phases. Information: C. H. Helliwell.

1.411J Building Construction I

(Same subject as 4.402J)
Prereq.: —
U (2)
3-4-5

See description under subject 4.402J.
E. Dluhosch

1.412J Building Construction II

(Same subject as 4.403J)
Prereq.: 1.02, 1.04; or 4.402J, 4.30 or 4.331
U (1)
2-4-3

See description under subject 4.403J.
R. Rush

1.413 Construction Technology and the Building Development Process (A)

Prereq.: —
G (1)
3-0-6

Investigates the nature of the building design and construction process with respect to the contractual, managerial, and financial implications of alternative technologies and construction methods. Particular attention to interfaces between various subsystems (e.g., structure, cladding, mechanical) and between design and construction activities. Uses cost estimating and scheduling as techniques to support analysis of alternatives.
J. M. Becker

1.42J Fundamentals of Energy in Buildings (New)

(Same subject as 2.45J, 4.42J)
Prereq.: 8.02, 18.02
U (1)
3-0-9

See description under subject 4.42J
L. Glicksman

1.421 Productivity and Competitiveness in Construction (A) (New)

Prereq.: —
G (1)
3-0-6

Course examines US competitiveness in domestic and international construction markets. Investigates factors and strategies for improving competitiveness at the firm level. The first part of the course treats the nature of productivity and its sources in technology, economics of scale, learning-by-doing, scientific management, and quality control. Second part addresses appropriate strategies and implementation plans for improving productivity and competitiveness.
A. H. Amsden

1.422 Management of Technological Innovation in Construction (A) (New)

Prereq.: —
G (2)
3-0-6

Course provides students with a better understanding of the issues and challenges involved in competing for construction on the basis of new technology. The course addresses which firms should innovate, when, where, and how much. It investigates specific cases of construction innovation in order to understand why some innovations fail while others succeed.
A. H. Amsden

1.431 Structuring Construction Industry Organizations (A)

Prereq.: —
G (2)
3-0-6

Examination, from a socio-technical perspective, of the organizations and organizational processes underlying the operation of the construction industry. Studies the structure and functioning of firms, sub-units of firms, and conglomerations of firms with regard to the influence of a wide range of factors including strategy, human and other resources, and role in the project development process. Frameworks for observation, description, analysis, and design of both individual enterprises and project organizations presented and applied to real-world situations.
H. G. Irwig

1.432 Project Control I (A) (Revised Content and Unit)

Prereq.: —
G (1)
3-0-9

Concepts, techniques, and computer systems for planning and control of design and construction projects. Relationship of project breakdown to performance measurement using estimating, scheduling, and financial control. Use of network-based systems for planning and time control, including CPM, PERT, and resource constrained scheduling. Integrating control of costs and time, with cash flow and manpower projections. Comparison of current practice with potential, stressing impacts of variance and role of knowledge in planning and control process.
R. D. Logcher

1.433 Project Control II (A) (Revised Content and Unit)

Prereq.: 1.432, 1.123
G (2)
3-0-9

Concepts and applications of database management to project control. Database and system design for integrated control systems. Systems development tools and process, including the use of applications generators, for construction applications. Role and techniques for the use of knowledge in such systems. Design of knowledge representations and knowledge based control systems. Term project developing database and/or knowledge based application.
R. D. Logcher

1.44 Law in the Construction Industry (A) (New)

Prereq.: —
G (2)
3-0-6

Examination of legal theories and relationships among various parties to construction process. Use of joint ventures, partnerships, limited partnerships, corporations, and professional corporations are considered in framework of qualifications for design and construction of public buildings, limitation of professional liability, and tax consequences. Construction contract types and key concepts and clauses are explained. Emphasis given to the role of design professional, construction manager or engineer in producing, managing, and interacting with legal profession.
J. B. Miller

1.45 Construction Finance (A)

Prereq.: —
G (2)
3-0-6

Examines financing methods and structure, project financial evaluation, and financial management in the domestic and international construction industry. Analytical concepts and methodologies from modern finance theory and practice presented in lecture/discussions and applied to case analyses including problems in cash flow analysis, project finance, and foreign exchange exposure. Innovative financial securities, and methods such as privatization and sale-leaseback are examined. Prior courses in microeconomics, accounting, and/or corporate finance desirable but not required.
J. L. Paddock

1.46 Automated Sensing of In Situ Conditions (A)

Prereq.: 8.02, 8.03 or equivalent
G (1)
3-0-6

Overview of measurement and sensory principles. Survey of information needs and current methods. Presentation of basic concepts of transducers, signal generation, data acquisition, signal and image processing, and data analysis and interpretation. Application of these concepts to specific techniques, including seismics, acoustics and vibration, ground-penetrating radar, infrared thermography, terrain conductivity, and machine vision. Case studies of specific applications of these techniques to site investigation, construction monitoring and control, and condition assessment.
K. R. Maser

1.481 Research Seminar in Construction Engineering and Management (A)

Prereq.: —
G (1,2)
1-0-2

Seminar intended mainly for master's and doctoral candidates in the Center for Construction Research and Education. Oral and written presentation by students on thesis activities and by faculty on research topics. Credit given in spring term only.
F. Moavenzadeh, C. H. Helliwell

1.482 Studies in Construction Engineering and Management (A)

Prereq.: —
G (1, 2, S)
Arr.

Individual study of an advanced topic in construction engineering and management, selected with approval of faculty supervisor.
F. Moavenzadeh

Structural Design and Analysis

1.50 Introduction to Structural Engineering

Prereq.: 1.04
U (1)
3-2-7

Basic philosophy of structural design. Loads on structures. Design criteria and factors of safety. Stress-strain relationships. Column theory. Application of statics to analysis of beams, trusses, and frames. Influence lines and moving loads. Deformation of structures. Indeterminate analysis. Design of components in steel. Structural connections.
E. Kausel

1.51 Mechanics of Construction Materials and Structures

Prereq.: 1.04
U (1)
4-0-8

Objective is to develop an intuitive feel of how load-bearing structures behave, study the influence of different construction materials on structural behavior, and develop the basic principles for quantifying the material and structural behavior. Includes problem formation, elasticity, elementary plasticity. Torsion, plane stress, and plane strain. Stress concentrations. Brittle fracture. Buckling. Thin shell structures. Design applications emphasized.
V. C. Li

1.52 Structural Analysis and Design

Prereq.: 1.50, 1.51
U (2)
3-1-8

Design and analysis of structural systems including steel and concrete frame buildings, and reinforced and prestressed concrete beam and slab structures. Contemporary design criteria and practice examined, with emphasis on concrete. Approximate and rigorous analysis techniques studied, with emphasis on their role in design process. Matrix methods of analysis. Use of computers in structural design. Plastic design in steel.
O. Buyukozturk

1.53 Constructed Facilities Project Laboratory

Prereq.: 1.04
U (2) LAB
0-3-3

Concepts, techniques, and devices used to measure engineering properties of materials. Emphasis placed on measurement of load-deformation characteristics of common construction materials, both natural and fabricated. Half-semester project devoted to experimental proof of hypothesis on some aspect of testing or behavior. Emphasis placed on approximation of testing errors.
J. T. Germaine

1.541 Behavior of Concrete Structures (A)

Prereq.: 1.52
G (1)
3-0-9

Strength and deformation of concrete under various states of stress; failure criteria. Fundamental behavior of reinforced concrete structures and their members. Basis for design, and code constraints. Bond and cracking, deflections. Slabs, yield line theory. Cylindrical concrete shells. Behavior models and nonlinear analysis. Complex systems: offshore gravity, containment, and bridge structures.
O. Buyukozturk

1.542 Behavior of Steel Structures (A) (Revised Unit)

Prereq.: 1.51
G (2)
3-0-9

Mechanical properties of steel. Yield criteria. Ductility. Fatigue failure. Stability considerations in member design. Structural connections. Stress concentrations. Residual stresses. Inelastic analysis procedures. Limit states. Computer methods for design.
J. H. Slater

1.543 Bridge Design (A)

Prereq.: 1.541, *1.542*
G (2)
3-0-6

Planning, design, and construction of bridges. Discusses bridge types and factors affecting the selection of type: concrete vs steel, prestressed, composite, segmental concrete bridges. Design issues and techniques. Detailed case study of a particular bridge. Recent technological developments in bridge engineering.
O. Buyukozturk

1.544 Structural Design of Buildings (A)

Prereq.: 1.541, *1.542*
G (1)
2-0-4

Structural systems for buildings. Special considerations in the design of high-rise buildings. Loads in buildings. Wind and earthquake effects. Comparisons of steel and concrete systems. Approximate methods for preliminary design. Case studies.
Information: O. Buyukozturk.

1.545 Fracture and Fatigue Behavior in Structural and Geo-materials (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Linear and non-linear fracture modeling; stability in material deformation; fracture and fatigue characterization; testing methodology; design for and against fracture failure; crack detection techniques; computer simulation of crack propagation; applications to structural materials, including steel, concrete, ceramics, and fiber-reinforced composites; and to geo-materials, including rock, over-consolidated clay, and ice.
V. C. Li

1.56J Structural Mechanics in Nuclear Power Technology (A)

(Same subject as 2.084J, 3.82J, 13.14J, 16.261J, 22.314J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 22.314J.
O. Buyukozturk, M. S. Kazimi

1.571 Advanced Structural Analysis (A) (Revised Unit)

Prereq.: 1.51
G (1)
3-0-9

Matrix methods for the analysis of member structural systems such as trusses and frames, considering geometric and material nonlinearity. Linear engineering beam theory. Curved members, arches, helical members. Restrained torsion. Numerical methods for the solution of nonlinear member systems.
J. J. Connor, Jr.

1.572 Advanced Structural Dynamics (A)

Prereq.: 1.35 or equivalent
G (2) **Next offered 1989-90**
3-0-9

Analysis of structures subjected to dynamic loads or earthquakes. Continuous and discrete systems by weighted residual methods. Solution of dynamic equations by convolution, time-step integration, modal superposition, complex modes, frequency-domain methods, and response spectrum techniques. Viscous, hysteretic, and frictional damping. Correspondence principle. Modal synthesis in frequency-domain. Substructuring techniques. Spatially periodic structures. Dynamic loads in layered media. Alternate years.
E. Kausel

1.588 Structural Engineering Research Seminar (A)

Prereq.: Permission of Instructor
G (2)
1-0-2

For structural engineering students registered for thesis or seeking research topics. Presentation of ongoing or proposed research by students. Occasional seminars by faculty or outside speakers. Participants required to submit written critique on each lecture.
J. J. Connor, Jr.

1.589 Studies in Structural Design and Analysis (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Individual study of advanced subjects under staff supervision. Content arranged to suit the particular requirements of the student and interested members of the staff.
Information: J. J. Connor, Jr.

Construction Materials

1.59J Materials of Construction

(Same subject as 3.143J)
Prereq.: 1.04
U (2) SD
3-0-9

Principles underlying the structure-properties interaction in materials important to civil engineers. Includes: atomic arrangements in crystalline and noncrystalline phases; thermodynamics of phase relationships and structural change; elasticity, microplasticity, viscoelasticity, and fracture; corrosion. Application of principles to structural metals, cementitious materials, structural-ceramics, wood, asphalt, and polymers. Mechanical properties of composite materials including Portland cement concrete, asphalt-aggregate mixtures, and reinforced plastics.
F. Moavenzadeh, F. J. McGarry

1.591J Fracture of Structural Materials (A)

(Same subject as 3.90J, 13.16J)
Prereq.: 1.59J or 2.30 or 3.141 or 13.15J
G (1)
3-0-6

See description under subject 3.90J.
F. J. McGarry, K. Masubuchi

1.592 Mechanical Behavior of Construction Materials (A)

Prereq.: —
G (2)
3-0-6

Develops an understanding of material behavior based on microstructural mechanisms of deformation. Includes study of elastic, plastic, creep, fracture, and durability behavior. Applications to traditional construction materials (steel, concrete, and timber) as well as recent developments in civil engineering materials (composites, ice mechanics).
L. J. Gibson

1.593J Mechanical Behavior of Plastics (A)

(Same subject as 3.91J)
Prereq.: 3.064
G (1)
3-2-4

See description under subject 3.91J.
F. J. McGarry

1.594J Composite Materials (A)

(Same subject as 3.92J)
Prereq.: 3.064
G (2)
3-2-4

See description under subject 3.92J.
F. J. McGarry

1.597 Studies in Construction Materials (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Advanced topics in construction materials selected by students for individual study with staff approval. Information: L. J. Gibson.

1.598 Research in Constructed Facilities

Prereq.: —
G (1, 2, S) [P/F]
Arr.

For research assistants in constructed facilities, when assigned research is not used for thesis, but is approved for academic credit. Credits for this subject may not be used for any degree granted by Course I.
Information: J. J. Connor, Jr.

1.599 Teaching in Constructed Facilities

Prereq.: —
G (1, 2) [P/F]
Arr.

For teaching assistants, in recognition of educational value derived from satisfactory performance of assigned duties, and for other qualified students interested in teaching in this area as a career. Laboratory, tutorial, or classroom teaching under supervision of a faculty member. Credits for this subject may not be used for any degree granted by Course I.
Information: J. J. Connor, Jr.

Water Resources and Environmental Engineering

Hydrodynamics and Coastal Engineering

1.60 Fluid Dynamics

Prereq.: 18.03
U (1)
4-0-8

Properties, states, and equilibrium of fluids. Conservation laws for control volumes. Equations of continuity and motion. Dynamic similitude, theory of models, and data presentation. Laminar and turbulent boundary layers. Flow in conduits and channels. Dynamic drag and lift forces on immersed objects. Turbulent jets and diffusion processes. Lectures supplemented by problem sessions.
P. S. Eagleson

1.62 Free Surface-Hydraulics

Prereq.: 1.60
G (2) **Next offered 1989-90**
3-1-8

Derivation of the one-dimensional form of the continuity, momentum, and energy equations. Boundary resistance. Steady uniform and nonuniform flow in open channels, including lateral in-outflow. Significance of the Froude Number; sub- and supercritical flow and channel transitions. Applications of momentum and energy principles. Flow controls: weirs, sluice gates, spillways, stilling basins. Unsteady flows: elements of floodrouting, overland flow, and oscillatory waves. Class project.
O. S. Madsen

1.63 Principles of Hydrodynamics (A)

Prereq.: 1.60
G (1)
3-0-6

An advanced account of dynamics of incompressible fluids. Materials are equally divided into four parts: 1) Basic formulation (kinematics, stress-strain, Navier-Stokes equations). 2) Potential flows (vorticity and circulation, analytic functions for two-dimensional problems, conformal mapping, flow through porous media). 3) Viscous flows and boundary layers (exact and approximate solutions). 4) Turbulent shear flows (instability, Reynolds equations, wall shear flows, and dispersion; free shear flows and plumes).
W. K. Melville

1.64 Dynamics of Stratified Fluids (A) (Revised Content)

Prereq.: 1.63
G (2) **Next offered 1989-90**
3-0-6

An advanced fluid mechanics subject treating the more important dynamical effects of stratification in natural fluid flows. An introduction to the conservation laws and basic thermodynamics is followed by treatment of linear and nonlinear internal waves; natural, forced, and double- diffusive convection; and selective withdrawal. The instability of stratified shear flows and the onset of turbulence are studied, as are methods of modeling fully developed turbulent boundary and mixing layers. The subject concludes with a study of the evolution of surface mixed layers in natural water bodies. Alternate years.
W. K. Melville

1.65 Experimental Methods in Hydrodynamics (A) (New)

Prereq.: 1.60
G (2) **Not to be offered 1989-90**
2-4-6

Introduces methods of experimental design, measurement, data acquisition, and analysis in hydrodynamics and environmental engineering. Presents measuring techniques, including laser-based optical, heat transfer, electromechanical and flow visualization. Emphasis is on laboratory techniques, but some examples are drawn from field methods in oceanography and meteorology. Lectures complemented by laboratory classes and more extensive term projects. Alternate years.
W. K. Melville

1.66 Problems in Water Resources and Environmental Engineering (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Advanced topics selected by students for individual study with staff approval. Choice of subjects from theoretical, experimental, and practical phases of hydromechanics, hydraulic engineering, water resources, and environmental engineering. Information: R. L. Bras.

1.67 Sediment Transport and Coastal Processes (A)

Prereq.: 1.60
G (2) **Not to be offered 1989-90**
3-0-6

Emphasizes the quantitative description of the mechanics of sediment transport in steady and unsteady flows based on hydrodynamic principles. Equations of motion for particles in a turbulent flow, entrainment, bedload, and suspended load. Bedform mechanics, ripples, dunes. Flow resistance and boundary-layer mechanics. Wave-induced longshore currents, longshore and on-offshore sediment transport. Coastal protection. Basic theory of water waves assumed known; contact instructor in early January.
O. S. Madsen

1.68 Physics of Environmental Transport (A) (Revised Content and Unit)

Prereq.: 1.60 or Permission of Instructor
G (1)
3-0-9

Treats physical transport processes in surface water, groundwater, and in the atmosphere with emphasis on exchanges across phase boundaries. Topics include sediment-water fluxes; gas exchange at the air-water interface; mass transfer from particles, droplets, and bubbles; deposition, coagulation, and filtration of particles; biofilms in porous media; canopy flow; small-scale dispersion and mixing of contaminants; interactions between mixing, transport, and reactions; linkages between physical, chemical, and biological processes.
K. D. Stolzenbach

1.69 Introduction to Coastal Engineering (A)

Prereq.: 1.60
G (1)
3-0-6

Basic hydrodynamics of waves in deep and shallow water. Linear theory, dispersion, superposition, spectral representation. Energy, energy transport, dissipation by bottom friction. Refraction, diffraction by breakwaters. Some nonlinear aspects, wave breaking. Emphasizes physical interpretation of mathematical results and their engineering application. Storm surges, coastal circulation, forecasting of wind-wave characteristics. Wind-wave statistics, wave forces on piles; breakwater stability.
O. S. Madsen

1.691 Wave Dynamics in Coastal Engineering (A) (Revised Unit)

Prereq.: 1.69, 1.131, or equivalent
G (2) **Next offered 1989-90**
3-0-9

Problems in water waves and currents of interest to coastal engineers. Emphasizes mechanical principles and theoretical methods of analysis. Topics chosen from the following areas: Ray theory of refraction, scattering of shallow-water waves, linearized theory of harbor oscillations. Diffraction by a breakwater. Effect of entrance losses. Mass transport due to viscosity. Radiation stresses and short-wave/long-wave interactions. Wave effects on poro-elastic sea beds. Alternate years.
C. C. Mei

1.692 Wave Dynamics in Oceanographic Engineering (A)

Prereq.: 1.69, 1.31, or equivalent
G (2) **Not to be offered 1989-90**
3-0-9

Problems in waves and currents. Transient aspects of dispersion and tsunamis. General theory of floating bodies, linearized radiation and diffraction, analytical and numerical aspects. Power absorption from sea waves. Nonlinear long waves in rivers or near a coast. Nonlinear short waves: slow modulation and instability of Stokes waves by slender or blunt

cylinders. Effects of currents or topography on wave evolution. Nonlinear waves in shallow water: solitons, harmonic generation, and resonances. Alternate years.
C. C. Mei

1.695J Principles and Physics of Remote Sensing in Oceanography (A)

(Same subject as 12.975J)
Prereq.: 1.60, 12.800
G (1) **Not to be offered 1989-90**
3-0-6

See description under subject 12.975J.
(Woods Hole Staff): H. C. Graber, K. A. Kelly

1.696J Oceanographic Applications of Remote Sensing (A)

(Same subject as 12.976J)
Prereq.: 1.695J and Permission of Instructor
G (2) **Not to be offered 1989-90**
0-3-6

See description under subject 12.976J.
(Woods Hole Staff): H. C. Graber, K. A. Kelly

1.697J Oceanographic Systems I

(Same subject as 13.990J)
Prereq.: —
G (S)
2-4-6

See description under subject 13.990J.
(Woods Hole Staff)

1.698J Oceanographic Systems II

(Same subject as 13.991J)
Prereq.: —
G (S)
2-4-6

See description under subject 13.991J.
(Woods Hole Staff)

1.699J Special Projects in Oceanographic Engineering (A)

(Same subject as 13.999J)
Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

See description under subject 13.999J.
(Woods Hole Staff)

Hydrology and Water Resource Systems

1.70 Analysis Methods in Water Resources and Environmental Engineering

Prereq.: 1.60
U (2)
3-3-6

Use of analysis tools (e.g., computer models) in the design and evaluation of water resources projects such as flood control, river basin development, and water quality. Lectures discuss governing principles, common models, and typical applications. In case studies, students may select/develop models, run simulations, perform experiments, or analyze data from field investigations. Results of the case studies are interpreted and discussed in written and oral reports. For advanced undergraduates or graduate students wishing exposure to broad applications. Some programming experience assumed.
E. E. Adams, D. McLaughlin

1.71 Introduction to Hydrology

Prereq.: 1.05
G (1)
4-0-8

Principles of meteorology and climate; earth water and energy balance; radiation; precipitation formation; evaporation; infiltration; runoff process. Streamflow analysis. Flood routing and rainfall-runoff models. Groundwater, well hydrology. Introduction to hydrologic probabilistic models. Deterministic, numerical, models in hydrology. Data analysis, design of collection systems. Useful for graduate students with no hydrology background.
R. L. Bras

1.711 Engineering Hydrology (A)

Prereq.: 1.03, 1.60, 1.71
G (2)
3-0-6

Models of hydrologic processes for selected engineering applications. Rainfall-runoff models, flood routing, urban hydrology, flood/drought frequency analysis, loss estimation, groundwater models, and storage analysis. Data sources for hydrologic models: instrumentation, measurement systems, remote sensing. Model limitations and the research-practice gap.
F. E. Perkins

1.712 Sampling, Synthesis, and Forecasting of Hydrologic Processes (A) (Revised Unit)

Prereq.: 18.444 or equivalent
G (2) **Not to be offered 1989-90**
3-0-9

The sampling, synthesis, and forecasting of signals in geophysics. Emphasizes hydrologic systems. Study of time series. Correlation and spectral analysis of periodic and aperiodic signals. Time and frequency domain analysis of random processes and fields. Stochastic simulation of rainfall and runoff. Estimation of static and dynamic systems. Kriging and Kalman filtering techniques. Applications in geology, oceanography, mining. Alternate years.
R. L. Bras

1.72 Groundwater Hydrology (A)

Prereq.: 1.60
G (1)
3-0-6

Introduces subsurface flow theory and applications; storage properties, Darcy equation, flow nets, mass conservation, the aquifer flow equation, heterogeneity and anisotropy, regional vertical circulation, unsaturated flow, and recharge. Well hydraulics, stream-aquifer interaction, distributed- and lumped-parameter numerical models. Groundwater quality, mixing cell models, contaminent transport processes, dispersion, decay and adsorption; pollution sources. Includes laboratory and computer demonstrations.
L. W. Gelhar

1.721 Advanced Subsurface Hydrology (A)

Prereq.: 1.72, 18.075
G (2)
3-0-6

Advanced treatment of flow in natural porous media with applications to resource development and environmental protection. Fluid transport processes in deformable media, boundary conditions, and problem formulation. Stochastic treatment of temporal and spatial variability. Contaminant transport, macrodispersion, tracer tests, salt water intrusion, heat transport, unsaturated flow and solute transport, flow and transport in fractured rocks. Large-scale behavior of heterogeneous media and uncertainty in model predictions. Permission of instructor required.
L. W. Gelhar

1.723 Subsurface Water Quality (A)

Prereq.: 1.72
G (1) **Next offered 1989-90**
3-0-6

Examines subsurface water quality problems from chemical and physical viewpoints. Physical transport of quality constituents, precipitation/dissolution reactions, adsorption chemistry, complexation, redox processes, microbial transformations, the role of particulates, and chemical influences on aquifer permeability. Development of a mass transport equation, and analytical and numerical solutions. Case studies of quality problems with emphasis on hazardous waste disposal. Alternate years.
H. F. Hemond

1.724 Groundwater Modeling (A) (Revised Unit)

Prereq.: 1.121, 1.72
G (2)
3-0-9

Development and application of numerical models for fluid flow and contaminant transport in porous media. Emphasis on finite difference, finite element, and collocation techniques. Analysis of data, implementation of boundary conditions, choice of discretizations. Single- and multi-phase systems. Some discussion of mathematical derivations of governing equations. Students develop computer codes for various physical systems of interest.
M. A. Celia

1.725J Chemicals in the Environment: Fate and Transport (A)

(Same subject as TPP 51J)
Prereq.: Permission of Instructor
G (1)
4-0-8

For Institute students in all departments interested in hazardous substance management (see TPP listings for other subjects). Emphasis on man-made chemicals, their movement through water, air, and soil, and their eventual fate in the environment. Coverage of specific topics is similar to 1.723, but for less specialized students. Analogous coverage of surface water and air fate and transport. Linkages to health effects, sources and control, and policy aspects.
H. F. Hemond

1.731 Water Resource Systems I (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Survey of deterministic optimization methods for management of large-scale water projects. Linear, integer, nonlinear, and dynamic programming illustrated with case studies. Applications include reservoir and irrigation development, conjunctive use of surface and groundwater, and hazardous waste remediation.
D. McLaughlin

1.732 Water Resource Systems II (A)

Prereq.: 1.151 or equivalent
G (2) **Next offered 1989-90**
3-0-6

Effects of uncertainty on water resource management. Quantitative methods for describing and analyzing uncertainty. Real-time estimation and control. Case studies include reservoir operations, groundwater resource development, water quality monitoring. Knowledge of optimization concepts and random processes required. Alternate years.
D. McLaughlin

Water Quality Control and Environmental Management

1.75 Limnology and Wetland Ecology (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

Dominant physical, chemical, and biological features of lakes and wetlands: basin geology, water budget, wind-driven hydromechanical phenomena, heat balance, thermal stratification, radiation environment, biological communities, and cycles of major elements. Characterization of wetlands, wetland biota, and chemical conditions of wetlands. Methodologies of modern limnology, including field methods and use of models; and current issues in lake and wetland management. Alternate years.
H. F. Hemond

1.76 Aquatic Chemistry (A)

Prereq.: 5.40 or 5.11
G (1) **Next offered 1989-90**
3-0-9

Quantitative treatment of variables that govern chemical behavior of aquatic systems such as lakes, oceans, rivers, estuaries, groundwaters, and wastewaters. Topics: thermodynamics, acids and bases, dissolved carbon dioxide, interactions between solid phases and solutes, coordination, and redox. Emphasis on quantitative study of model systems. Interactions between physical, chemical, and biological variables in natural waters stressed. 5.60 is a suggested prerequisite.
F. M. M. Morel

1.77 Water Quality Control (A)

Prereq.: 1.60
G (1)
3-0-6

Emphasis on mathematical models for predicting distribution and fate of effluents discharged into lakes, reservoirs, rivers, estuaries, and oceans; and on formulation and structure of models rather than on solution techniques. Role of element cycles, such as oxygen, nitrogen, and phosphorus, as water quality indicators. Offshore outfalls and diffusion. Salinity intrusion in estuaries. Thermal stratification in lakes and reservoirs and sedimentation processes.
D. R. F. Harleman

1.79 Aquatic Ecology (A)

Prereq.: —
G (1)
3-0-6

Basic graduate subject dealing with selected aspects of the ecology of marine and freshwater systems. Emphasizes physiological processes of phytoplankton, but includes bacteria and other aquatic microorganisms. Focus is on organism/environment interactions. Topics include photosynthesis, primary and secondary production, nutrient limitation and uptake kinetics, element cycles, population growth, and chemostat theory. Lecture/seminar format with extensive outside readings.
S. W. Chisholm

1.80 Fundamentals of Ecology

Prereq.: —
U (2)
3-1-8

Basic subject dealing with ecological science; principles of interrelationships between organisms and their environment. Development of basic concepts of energy flow and element cycles in ecosystems; productivity; trophic dynamics; community structure and stability; competition and predation; evolution and natural selection; population growth; and physiological ecology. Emphasis on acquatic systems.
S. W. Chisholm

1.811J Environmental Law: Pollution Control (A)

(Same subject as TPP 33J)
Prereq.: —
G (1)
3-0-6

Reviews and analyzes Federal and state regulation of air and water pollution and hazardous wastes. Emphasizes use of legal mechanisms and alternative approaches (such as economic incentives) to control pollution. Focuses on the major Federal legislation, the underlying administrative system, and the common law in analyzing the goals of pollution control, economic consequences, and the role of the courts. Discusses both classical pollutants and toxic industrial chemicals. Also provides an introduction to basic legal skills.
N. A. Ashford, C. C. Caldart

1.812J Regulation of Chemical Toxins, Radiation, and Biotechnology (A)

(Same subject as TPP 34J)
Prereq.: Any prior law course or Permission of Instructor
G (2)
3-0-6

Focuses on policy design and evaluation in the regulation of hazardous substances and processes. Includes risk assessment, hazardous chemical wastes, toxic air and water pollutants, pesticides, food additives, pharmaceuticals, radiation and radioactive wastes, product safety, the Toxic Substances Control Act, workplace toxins, biotechnology, and victims' compensation. Both health and economic consequences of regulation discussed.
N. A. Ashford, C. C. Caldart, D. B. Hattis

1.82 Problems in Aquatic Biology and Chemistry (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

Advanced topics in fields of aquatic chemistry and aquatic biology. Choice of independent study seminar, laboratory, or field studies. Typical topics include analytical and bioassay methodologies, nutrient and trace-metal interactions with aquatic biota, element cycles.
S. W. Chisholm, F. M. M. Morel

1.83 Environmental Organic Chemistry (A)

Prereq.: 5.41 or 5.12
G (1)
3-0-6

After describing the cycling of natural organic matter in aquatic environments, focus shifts to processes affecting anthropogenic organic compounds. Uses physical chemical properties to predict chemical transfers between environmental compartments (air, water, sediments, biota). Uses molecular structure-reactivity relationships to estimate chemical, photochemical, and biochemical transformation rates. Resulting models predict environmental concentrations (and related biological exposures) of hazardous and natural organics in water resources.
P. M. Gschwend

1.84 Aquatic Particles (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

An advanced graduate course on the physical chemistry of particles in natural waters. Nature of aquatic particles. Basic surface chemistry of solids in water. Double-layer theory. Thermodynamics of adsorption. Adsorption models, equilibrium, and kinetics. Mixed phase solids. Particle interactions. Stability of suspensions. Coagulation theory. Size distributions. Role of coagulation and biota in sedimentation. Alternate years.
F. M. M. Morel, K. D. Stolzenbach

1.85 Wastewater Treatment Engineering

Prereq.: 1.60 or 1.80
G (2)
3-0-6

Theory and design of treatment systems for muncipal wastewater. Theory of mixing and transport in reactor vessels. Biochemical processes related to the carbon, oxygen, nitrogen, and phosphorus cycles. Completely mixed and plug flow reactors with and without recycle. Activated-sludge systems and sludge digesters. Fixed-film processes, adsorption, sedimentation, and other physical, chemical, and biological processes.
D. R. F. Harleman

1.898 Research in Water Resources and the Water Environment

Prereq.: —
G (1, 2, S) [P/F]
Arr.

For research assistants in water resources and the water environment, when assigned research is not used for thesis, but is approved for academic credit. Credits for this subject may not be used for any degree granted by Course I. Information: R. L. Bras.

1.899 Teaching in Water Resources and the Water Environment

Prereq.: —
G (1, 2) [P/F]
Arr.

For teaching assistants, in recognition of the educational value derived from satisfactory performance of assigned duties, and for other qualified students interested in teaching in this area as a career. Laboratory, tutorial, or classroom teaching under supervision of a faculty member. Credits for this subject may not be used for any degree granted by Course I. Information: R. L. Bras.

Special Studies

1.91 Civil Engineering Internship

Prereq.: —
U (1, 2, S) [P/F]
0-6-0

1.92 Advanced Civil Engineering Internship

Prereq.: 1.91
G (1, 2, S) [P/F]
0-6-0

1.91 provides credit for the first two work assignments of Course I students affiliated with the Engineering Internship Program. 1.92 provides credit for the third and fourth work assignments for students affiliated with the Engineering Internship Program. Students register for both 1.91 and 1.92 twice and must complete both work assignments in order to receive academic credit for the subjects. Enrollment limited to students registered in the Course I Internship Option.
Information: O. Buyukozturk.

1.961-1.966 Special Graduate Studies in Civil Engineering (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Graduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest. Information: O. S. Madsen.

1.968 Graduate Studies in Civil Engineering

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Individual study, research, or laboratory investigations at the graduate level, under faculty supervision. Information: O. S. Madsen

1.969 Graduate Studies in Civil Engineering (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Individual study, research, or laboratory investigations at the graduate level, under faculty supervision. Information: O. S. Madsen.

1.980J Leadership Seminar in Technology and Policy (A)

(Same subject as TPP 13J)
Prereq.: Thesis Registration
G (2)
2-0-1

See description under subject TPP 13J.
R. de Neufville

1.991, 1.992 Special Undergraduate Studies in Civil Engineering

Prereq.: Permission of Instructor
U (1, 2)
Arr.

Undergraduate subjects taught experimentally; special subjects offered by visiting faculty; seminars on topics of current interest. Information: K. D. Stolzenbach.

1.999 Undergraduate Studies in Civil Engineering

Prereq.: —
U (1, 2, S)
Arr.

Individual study, research, or laboratory investigations under faculty supervision. Information: K. D. Stolzenbach.

Course 2 Mechanical Engineering

2.UR Undergraduate Research in Mechanical Engineering

Prereq.: —
U (1, 2, S) [P/F]
Arr.

Individual study, research, or laboratory investigations under faculty supervision, including individual participation in an ongoing research project. Coordinator: D. G. Wilson.

Mechanics, Dynamics, and Acoustics

2.01 Mechanics of Solids

Prereq.: 8.01, 18.02
U (1, 2) SD
4-0-8

Introduces mechanics of continuous deformable media, emphasizing three-dimensional requirements of force equilibrium, geometric compatibility, and constitutive behavior. Stress and its relation to force and moment. Strain and its relation to displacement. Linear elasticity with thermal expansion. Failure modes. Applications to stress distributions and beformations of rods, shafts, beams, and other simple structures of engineering importance. Emphasizes computer methods and matrix structural analysis.
M. P. Cleary, D. G. Karr

2.02 Introduction to Systems Dynamics

Prereq.: 8.01, 18.02
U (1, 2) SD
4-0-8

Dynamic modeling by linear and nonlinear lumped multiport elements of physical systems. Unified treatment of active and passive mechanical, fluid, electrical, thermal, and electronic devices and systems. Concept of state and state variables. Formulation and solution of state equations by direct analysis, and by digital computer methods. Dynamic response and stability of linear systems. System functions, pole-zero configurations, and their interpretation. Generalized impedance and source equivalents. Extensive use of engineering examples.
D. Rowell

2.03J Dynamics

(Same subject as 13.003J)
Prereq.: *2.01*, 2.02, 18.03
U (1, 2)
4-0-8

Dynamics of lumped and continuous models of mechanical, electrical, and electro-mechanical systems. Kinematics and dynamics of rigid bodies in two- and three-dimensional motions. Formulation of equations of motion by momentum principles and Lagrange's equations. Behavior of linearized models: natural modes and frequency response of lumped systems, wave transmission and reflection in continuous systems.
J. H. Williams, Jr., J. K. Vandiver

2.032 Dynamics (A)

Prereq.: 2.03J
G (1)
3-0-9

Momentum principles and energy principles. Lagrange equations, Hamilton's principle. Applications to mechanical systems including gyroscopic effects. Study of steady motions and nature of small deviations therefrom. Natural modes and natural frequencies for continuous and lumped parameter systems. Forced vibrations. Dynamic stability theory. Causes of instability.
S. H. Crandall

2.034 Nonlinear Dynamics (A)

Prereq.: 2.032
G (2)
3-0-9

A unified treatment of nonlinear phenomena in the dynamics of discrete and continuous systems. Qualitative methods of analysis, phase plane techniques. Quantitative analysis of weakly nonlinear systems in free and forced vibrations; perturbation methods, nonlinear resonances, self-excited oscillations, lock-in phenomena. Introduction to nonlinear stability and bifurcation theory, nonlinear wave propagation, solutions. Applications are made to mechanical, fluid, electrical, and flow-structure interaction problems.
T. R. Akylas

2.05 Kinematics and Dynamics of Mechanisms and Manipulators (A)

Prereq.: 2.03J
G (1) **Next offered 1989-90**
3-0-9

Analyzes kinematic and dynamic characteristics of planar and spatial mechanisms, including machines and robotic manipulators. Use of vector, graphical, and 4 by 4 matrix methods for kinematic analysis. An introduction to graphical and computer methods for kinematic synthesis of mechanisms. Methods for dynamic analysis of mechanisms, and the use of digital simulation techniques. Systems include rigid and flexible elements and active control systems. Applications from industrial machine systems and robotic manipulators.
S. Dubowsky, H. West

2.06J Mechanical Vibration

(Same subject as 13.80J)
Prereq.: 2.03J or 13.003J
U (2)
3-0-9

See description under subject 13.80J.
R. H. Lyon, J. K. Vandiver

2.060J Principles of Acoustics (A)

(Same subject as 13.81J, 16.081J)
Prereq.: 2.03J or 16.004, 18.075
G (1)
3-0-9

Combined with subject 2.063, forms a two-term sequence in acoustics at advanced level; subjects may be taken in any order. Emphasizes acoustics of fluids: derivation of basic equations, radiation of sound, diffraction and scatterings. Acoustic, thermal, and vorticity fluctuations as first order perturbation of equations of fluid dynamics; energy density and intensity. Multipole expansions of source fields, spherical harmonics, radiation impedance and directivity. Scattering and diffraction of sound by obstacles. Moving sources. Aeroacoustics.
P. Leehey, R. H. Lyon

2.061 Random Vibration (A)

Prereq.: 2.03J, 18.075
G (2)
3-0-9

Description of stochastic processes. Impulse response and frequency response of linear time-invariant dynamic systems. Correlations and spectra of stationary response. Crossing rates, peaks, and envelopes. Failure under random loading. Poisson pulse processes. Measurement, identification, and response problems. Coherence. Space-time correlations and cross-spectra. Digital data processing. Cepstrum analysis. Applications to vehicles and structures subjected to wide-band random excitation.
S. H. Crandall

2.062 Wave Propagation (A)

Prereq.: 2.03J, 18.075
G (2) **Next offered 1989-90**
3-0-9

Wave concepts in applied mechanics with examples chosen from elasticity, acoustics, geophysics, hydrodynamics, and related subjects. Plane wave theory, dispersion, phase and group velocities, wave impedance, energy density and intensity. Theory of characteristics. Reflection and refraction, wave guides, and boundary waves. WKB method, Green's law, and wave action. Generation, transmission, and reception of waves. Water-hammer waves, Rayleigh waves, waves in periodic structures.
T. R. Akylas

2.063J Sound and Structural Vibration (A)

(Same subject as 13.82J)
Prereq.: 2.03J or 16.004, or 18.075
G (2)
3-0-9

With subject 2.060J, forms a two-term sequence in acoustics at advanced level; to be taken in any order. Transmission of vibration in structures and interaction with sound fields. Dynamics of sound fields and longitudinal, shear, and flexural vibrations. Normal modes, phase and group velocity, energy decay. Radiation impedance and input and transfer mobility of structural elements. Statistical energy analysis, reciprocity, energy sharing between structures and sound fields.
R. H. Lyon, P. Leehey

2.066 Machinery Noise and Diagnostics

Prereq.: —
G (1)
3-0-9

Uses basic ideas about vibration generation and transmission and sound radiation in design of quieter machines. Excitation mechanisms are impact, dimensional variations, and fluid flow. Vibration transmission models include transmission line and S.E.A. Criteria for acceptable levels of noise and vibration are discussed. Vibration signatures in time and frequency domains for diagnostic purposes are described. Energy vs time and vs frequency, and waveform reconstruction are discussed as techniques for obtaining diagnostic signatures.
R. H. Lyon

2.071J Introduction to Structural Mechanics

(Same subject as 13.10J)
Prereq.: 2.01 or 2.015
U (1)
4-0-8

See description under subject 13.10J.
J. H. Williams, Jr., D. G. Karr, A. Moshaiov

2.072 Mechanics of Continuous Media (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Principles and practical application of continuum concept for deformation of solid, fluid, or multiphase bodies. Kinematics and thermomechanic conservation laws through comprehensive tensor notation. Stress and strain measures and constitutive equations. Solution of many basic problems for various materials as relevant in metallurgy, materials processing, geomechanics and fluid dynamics, fracture mechanics and structural analysis. Analytical and numerical solution methodology for differential and integral equations.
M. P. Cleary

2.073 Solid Mechanics — Plasticity and Inelastic Deformation (A)

Prereq.: 2.30
G (1)
3-0-9

Focuses on analysis of inelastic deformations of solids, emphasizing behavior of polycrystalline metals. Develops continuum constitutive models including consideration of physical bases of deformation. Limit analysis of continua, structures, and polycrystalline aggregates. Variational formulations of governing equations including finite element implementation. See also 13.131 and 16.24.
D. M. Parks

2.074 Applications of Mechanics for Porous/Geological Materials (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Extension of continuum mechanics to fluid-infiltrated porous media: coupled heat/fluid flow and solid deformation/frictional yielding/fracture. Constitutive relations, micromodeling, localization instabilities, and structural analysis. Laboratory simulation. Examples from energy and materials resources, prospecting and extraction: machine excavation, oil/gas drilling/fracturing, solution mining, geothermal; from geophysics: wave propagation, earth-fault mechanisms, igneous intrusions; and from biomechanical load-bearing elements.
M. P. Cleary

2.083 Applied Elasticity (A)

Prereq.: 2.01, *18.075*
G (1)
3-0-9

Introduces the theory and applications of linearized elasticity. Review of kinematics, kinetics, and the constitutive law. Anisotropic material behavior. Several of the following topics: plane problems; singular problems involving cracks, point loads, dislocations. Torsion of noncircular cylinders. Energy theorems and applications. Linear elastic fracture mechanics. Fundamental three-dimensional problems. Variational principles and applications. Structural mechanical approximations for beams, plates, and shells. Introduction to wave propagation.
J. H. Williams, Jr., R. Abeyaratne

2.084J Structural Mechanics in Nuclear Power Technology (A)

(Same subject as 1.56J, 3.82J, 13.14J, 16.261J, 22.314J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 22.314J.
O. Buyukozturk, M. S. Kazimi

2.092 Methods of Engineering Analysis (A)

Prereq.: 18.075
G (1)
3-0-9

Study of nature of complex problems in engineering analysis and of means of obtaining practical solutions. Survey of formulations of mathematical models for complex physical situations and of computational procedures for their solution. Examples chosen from mechanics, hydraulics, heat transfer, elasticity, compressible flow, etc. Numerical methods including iteration, variational, finite difference, and finite element methods.
K. J. Bathe, T. R. Akylas

2.093 Computer Methods in Dynamics (A)

Prereq.: 2.03J, 18.075
G (2)
3-0-9

Formulation of finite element methods for analysis of dynamic problems in solids, structures, fluid mechanics, and heat transfer. Computer calculation of matrices and numerical solution of equilibrium equations by direct integration and mode superposition. Effective eigensolution techniques for calculation of frequencies and mode shapes. Digital computer coding techniques and use of an existing general purpose finite element analysis program. Modeling of problems and interpretation of numerical results.
K. J. Bathe

2.094 Theory and Practice of Continuum Mechanics (A)

Prereq.: 2.01, 18.075
G (1) **Not to be offered 1989-90**
3-0-9

Basic principles of continuum mechanics and finite element methods, modern application to solution of practical problems in solid, structural, and fluid mechanics, heat and mass transfer, other field problems. Kinematics of deformation, strain and stress measures, constitutive relations, conservation laws, virtual work, and variational principles. Discretization of governing equations using finite element methods. Solution of central problems using existing computer programs.
K. J. Bathe

System Dynamics and Control

2.10 Elementary Programming and Machine Computation

Prereq.: —
U (1, 2)
3-2-4

Introduces the use of digital computers in science and engineering. FORTRAN, the most popular language for scientific applications, is used. Covers fundamentals of digital computation, outlines numerical techniques, character manipulation, simulation and software development. Some topics — e.g., graphics or introduction to C — vary by semester. Problems include examples from many disciplines. Assumes no prior computing experience.
D. Rowell, S. H. Kim, I. Paul

2.101 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

2.11 Intelligent Systems Design (New)

Prereq.: —
U (2)
2-0-7

Principles and techniques for the design of intelligent systems through knowledge engineering, neuroscience, cognitive science, systems theory, and information models. Strengths and limitations of existing methodologies as well as present applications and future developments. Topics include: frameworks, knowledge representation, information processing, reasoning, logic programming, expert systems, design principles, and applications. Practice in design through individual and group projects.
S. H. Kim

2.14 Control System Principles

Prereq.: 2.02
U (1, 2)
3-2-7

Introduction to analysis and synthesis of feedback systems. Functional description of linear and nonlinear systems. Block diagrams and signal flow graphs. State-space representation of dynamical systems. Transient response using convolution integral and computational techniques. Root locus and frequency response methods. Performance indices and error criteria. Controller realization. Examples of pneumatic, hydraulic, electronic, and electromechanical control systems.
D. Rowell

2.141 Modeling and Simulation of Dynamic Systems (A)

Prereq.: 2.151
G (1) **Not to be offered 1989-90**
3-0-9

Mathematical modeling of complex engineering systems at a level of detail compatible with the design and implementation of modern control systems. Wave-like and diffusive energy transmission systems. Multiport energy storing fields and dissipative fields; consequences of symmetry and asymmetry. Nonlinear mechanics and canonical transformation theory. Examples will include mechanisms, electromechanical transducers, electronic systems, fluid systems, thermal systems, compressible flow processes, chemical processes.
N. Hogan

2.151 Advanced System Dynamics and Control (A)

Prereq.: 2.02, 2.14, 18.06
G (1, 2)
3-0-9

Analytical and graphical descriptions of state-determined dynamic physical systems; time and frequency domain representations; system characteristics—controllability, observability, stability; linear and nonlinear system responses. Modification of system characteristics using feedback. State observers, Kalman filters. Modeling/performance trade-offs in control system design. Emphasis on application of techniques to physical systems.
N. Hogan, D. Rowell

2.152 Advanced Control System Design (A)

Prereq.: 2.151 or 2.154; or equivalent
G (2)
3-0-9

Introduction to advanced methods in linear and nonlinear control system design. Linear multivariable state-space techniques: eigenstructure placement, state-observers, discrete Kalman filtering. Nonlinear stability theory: model-reference adaptive control, applied nonlinear control system design, optimal control. Emphasis on applications to physical systems and the modeling/performance trade-offs.
J-J. E. Slotine

2.153 Nonlinear Analysis and Control Methods (A)

Prereq.: 2.151
G (1) **Next offered 1989-90**
3-0-9

Fundamental properties of nonlinear systems: multiple equilibrium points, limit cycles, jump resonances. Simulation of nonlinear dynamic systems, deterministic and stochastic. Phase plane methods, extensions to higher order systems via bifurcation and catastrophe theory. Lyapunov stability theory and application to sliding mode and model reference adaptive control. Equivalent linearization methods including sinusoidal and random input describing functions. Controller design via describing function methods.
J. K. Hedrick

2.154J Multivariable Control Systems I (A)

(Same subject as 6.233J, 10.28J, 13.481J, 16.341J)
Prereq.: 2.14 or 6.302 or 10.35 or 16.30
G (1)
4-0-8

See description under subject 6.233J.
J. K. Hedrick, M. Athans, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

2.155J Multivariable Control Systems II (A)

(Same subject as 6.234J, 10.29J, 13.482J, 16.342J)
Prereq.: 6.233J
G (2)
4-0-8

See description under subject 6.234J.
J. K. Hedrick, M. Athans, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

2.157J Design and Implementation of Computer-Aided Engineering Systems (A)

(Same subject as 13.471J)
Prereq.: Permission of Instructor
G (1)
3-2-7

Overview of existing CAE systems; architecture of high-performance graphic displays in engineering workstations; orthographic and perspective display transformations; parametric representation of curves and surfaces; elementary differential geometry; interactive graphics; bicubic surface patches; image generation; NC tool paths; solid modeling; advanced research topics; project management for software development. Group projects emphasize CAE system development. Programming proficiency required.
D. C. Gossard, N. M. Patrikalakis

2.158J Computational Geometry (A) (New)

(Same subject as 13.472J)
Prereq.: 2.157J
G (2)
3-0-9

Continuation of 2.157J with lectures, homeworks, and individual projects focusing on advanced research topics. Algebraic and rational polynomial parametric representation methods. Intersections and algebraic geometry. Sweeps. Blending and parallel surfaces. Trimmed patches. Solid modeling: CSG, boundary representation, octrees. Variational geometry and tolerances. Feature representation and recognition. Finite element discretizations. Interrogation of geometric models for design, analysis, and fabrication.
N. M. Patrikalakis, D. C. Gossard

2.171 Analysis and Design of Digital Control Systems (A)

Prereq.: 2.151; 2.14
G (2)
3-3-6

A comprehensive introduction to control system synthesis in which the digital computer plays a major role, reinforced with hands-on laboratory experience. Covers elements of real-time computer architecture; input-output interfaces and data converters; analysis and synthesis of sampled-data control systems using classical and modern (state-space) methods; analysis of trade-offs in control algorithms for computation speed and quantization effects. Laboratory projects emphasize practical digital servo interfacing and implementation problems with timing, noise, nonlinear devices.
W. Durfee, D. Rowell

2.18J Human Factors in Design

(Same subject as 9.39J, 22.088J)
Prereq.: Permission of Instructor
U (2)
3-1-8

Analyzes human and computer roles, interfacing and reliability in nuclear and chemical plants, air traffic control, industrial robots, office automation, and other systems. Introduces methods for measurement of and statistical inference about human behavior in such interactions. Reviews human sensory and motor performance characteristics and the derivation of human engineering design criteria for displays and controls. Readings from the human factors engineering literature. Case studies and design projects.
T. B. Sheridan, D. D. Lanning, A. Hein

2.181J Models of Man-Machine Systems (A)

(Same subject as 16.355J)
Prereq.: 18.03
G (1)
3-1-8

Introduces mathematical models of human performance and man-machine interaction. Psychophysical methods. Theory and models of manual control, supervisory control, information transmission, signal detection, Bayesian decision making. Multi-attribute utility, fuzzy set, and other judgment scaling techniques. Applications to process control, aircraft, and robotic systems. Readings from the literature. Laboratory demonstrations and case studies. Permission of instructor required.
T. B. Sheridan, S. R. Bussolari

2.192 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. de Neufville, J. P. Clark

Fluid Mechanics and Combustion

2.20 Fluid Mechanics

Prereq.: 18.02, *18.03*
U (1, 2) SD
4-0-8

Introduces incompressible flows. Hydrostatics. Mass conservation equation. Differential equation of motion for inviscid flows. Bernoulli's equation. Linear and angular momentum theorems and applications to engineering problems. Vorticity and irrotational flows. Equations governing viscous fluid flow, and some special solutions. Boundary layers. Dimensional analysis and modeling, with application to flow problems. Conservation of energy. Flows with head losses and gains in ducts and pipes.
J. A. Fay

2.22 Computational Methods in Engineering

Prereq.: 18.03, 2.10
U (1)
3-0-9

Numerical methods widely used in analysis of models arising in engineering. Approximation and integration schemes, solution of algebraic, ordinary, and partial differential equations using finite difference and finite element methods. Applications from heat transfer, fluid, and solid mechanics. Emphasis on model formulation, choice of algorithms, error estimates, and interpretation of results. Homeworks include computer assignments.
A. Ghoniem

2.25 Advanced Fluid Mechanics (A)

Prereq.: 2.20, *18.075 or 18.085*
G (1)
3-0-9

Surveys principal concepts and methods of fluid dynamics. Statics. Fluid kinematics. Continuity, momentum, and energy relations for continuous fluids. Vorticity dynamics. Circulation. Kelvin's and Helmholtz's theorems. Dynamical similarity in fluid flows. Navier-Stokes equations for viscous fluids and applications. Lubrication theory. Boundary layer theory, including separation and other examples of shear flow phenomena. Introduction to turbulence. Drag. Lift.
A. A. Sonin

2.271 Compressible Fluid Mechanics (A)

Prereq.: 2.20, 2.40
G (2)
3-0-9

Fundamental survey of compressibility effects in transient and steady flows. Examples from engineering practice. Steady one-dimensional flows with area change, shock waves, friction, and energy exchange. Unsteady one-dimensional flows: wave phenomena, method of characteristics, shocks, and rarefactions. Steady, two-dimensional subsonic and supersonic flows: method of characteristics, standing shock waves. Numerical methods for compressible flows.
R. D. Kamm

2.272J Physicochemical Hydrodynamics (A)

(Same subject as 10.53J)
Prereq.: 2.25 or 10.50
G (1)
3-0-9

Fundamentals of physical-chemical interactions with fluid flow including aspects of biomolecular hydrodynamics. Transport of mass, heat, and charge in laminar flow. Particle-liquid flows with and without charge effects. Macromolecules as hydrodynamic particles with application to separation processes. Surface tension, phase change, and chemical reactions in flows. Suspension rheology.
R. F. Probstein, H. Brenner

2.273 Turbulent Flow and Transport (A)

Prereq.: 2.25
G (2)
3-0-9

Turbulent flows, with emphasis on engineering methods. Governing equations for momentum, energy, and species transfer. Turbulence: its production, dissipation, and scaling laws. Averaged (Reynolds) equations for momentum, energy, and species transfer. Simple closure approaches for free and bounded turbulent shear flows: jets, pipe and channel flows, boundary layers, plumes, dispersion problems, etc., including heat and species transport as well as flow fields. Introduction to more complex closure schemes and statistical methods in turbulence.
A. A. Sonin

2.274 Computational Fluid Dynamics (A)

Prereq.: *2.25*
G (1)
3-0-9

Techniques for the numerical simulation of viscous incompressible flows. Spatial discretization: finite-difference, finite-element, spectral methods. Time-stepping. Accuracy, stability, and generality considerations. Numerical diffusion, dispersion. Vorticity-streamfunction and primitive-variable formulations. Examples from internal and external flows, heat transfer. Familiarity with elementary numerical analysis helpful. Computer assignments requiring knowledge of FORTRAN.
A. T. Patera

2.275 Turbomachinery Design (A)

Prereq.: 2.20 or 2.25; 2.40 or 2.41J
G (1) **Not to be offered 1989-90**
3-0-9

Momentum transfer in turbomachines. Axial- and radial- flow compressors and turbines: design considerations, cascade fluid mechanics including effects of viscosity and compressibility and three-dimensional flow, performance limitations; cavitation. Alternate years.
D. G. Wilson

2.277 Biomedical Fluid Mechanics (A)

Prereq.: 2.20
G (2)
3-0-9

Engineering approach to the function of circulatory and respiratory systems and to other problems in physiology involving fluid dynamics. Reviews relevant anatomy and physiology emphasizing quantitative considerations. Presents and discusses mathematical or engineering models in relation to physiological phenomena they are intended to simulate. Directed to graduate students in Engineering and Science, but open to medical students and undergraduates with the permission of the instructor. Alternate years.
R. D. Kamm

2.281 Reacting Gas Dynamics (A)

Prereq.: 2.20 or 16.02 and 2.40
G (1) **Next offered 1989-90**
3-0-9

Treats problems in non-equilibrium gas dynamics involving simultaneous occurrence of chemical reaction and transport of mass, momentum, and energy. Applied chemical kinetics. Conservation equations considering chemical reaction and multispecies diffusion. Relaxation phenomena. Method of characteristics for non-equilibrium flows. Acoustic waves, shocks, flames, detonations; their propagation and structure. Chemical lasers, hypersonic flows, turbulence-combustion interactions. Modeling and numerical simulation of reacting flows. Engineering applications. Alternate years.
A. F.Ghoniem

2.282 Combustion (A)

Prereq.: 2.20 or 16.02 and 2.40
G (1) **Next offered 1989-90**
3-0-9

Comprehensive treatment of combustion principles and their applications. Flammability and explosion limits. Diffusion and premixed flames. Laminar and turbulent combustion. Ignition, propagation, and stabilization. Combustion instability. Exothermic hypersonic flows. Supersonic combustion. Droplet, jet and coal combustion. Engine combustion. Fire research. Modeling and numerical simulation of combustion processes. Alternate years.
A. F. Ghoniem

2.29J Air Pollution Control

(Same subject as 10.71J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Common gaseous and particulate air pollutants and their environmental effects. Modeling of atmospheric chemical and physical processes that disperse, transport, transform, and remove air pollutants on local, regional, and global scales. Formation of air pollutants in combustion processes. Control technology and costs. Regulation of air quality and emissions.
J. A. Fay, A. F. Sarofim

Materials

(See also listing under Polymers and Fibers)

2.30 Mechanical Behavior of Materials

Prereq.: 2.01, 2.671, *2.86*
U (1, 2)
4-1-10

Introduces mechanical behavior of engineering materials. Emphasizes a combined materials science and continuum mechanics approach. Major topics: linear elasticity, linear viscoelasticity, rate-independent plasticity, rate-dependent plasticity, linear elastic fracture mechanics, creep fracture, and fatigue failure. Laboratory experiments involving a variety of materials, testing methods and analyses, and a special project.
L. Anand, D. M. Parks

2.301 Advanced Mechanical Behavior of Materials (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Selected topics treated from the atomic to the applied level for insights into a variety of materials and applications. Deformation in elasticity, rubber elasticity, viscosity, creep, and plasticity (with some slip line fields); viscoelastic shift factor and superposition. Monotonic and fatigue crack initiation and growth in ductile and brittle structures. Hardness, friction, wear. High-strength materials, composites. Requires background in materials or mechanics. Text: McClintock, Argon, *Mechanical Behavior of Materials,* and notes.
F. A. McClintock

2.302J Physics of Inelastic Deformation of Solids (A)

(Same subject as 3.25J)
Prereq.: 2.30 or 2.301
G (2) **Not to be offered 1989-90**
3-0-9

Rate mechanisms in crystal plasticity, kinetics and dynamics of slip, superposition of flow stress mechanisms. Inelastic deformation in non-metals, visco-plasticity of metallic, inorganic, and polymeric glasses; plasticity of crystalline polymers; statistical theory of elastomeric behavior. Macro-plasticity in polycrystalline metals and in polymers. Strain hardening and recovery. Macroscopic three-dimensional constitutive relations for inelastic deformation, usable in computational mechanics. Alternate years.
A. S. Argon

2.303J Micro Mechanisms of Fracture (A)

(Same subject as 3.26J)
Prereq.: 2.30 or 2.301
G (2) **Next offered 1989-90**
3-0-9

Fundamental crack tip solutions. Cohesive strength of pure solids and interfaces. Microcrack initiation. Brittle fracture in tension and compression. Static fatigue. Toughening of brittle solids by crack tip shielding. Ductile fracture by plastic cavitation. Intergranular fracture at elevated temperatures. Brittle to ductile transitions in fracture. Fracture of composites. Fracture in cyclic deformation. Examples drawn from all prominent structural solids. Alternate years.
A. S. Argon

2.34J The Mechanics of Fracture

(Same subject as 3.41J)
Prereq.: 2.30
G (2)
3-0-9

The understanding and prevention of fracture of engineering materials requires an integration of basic concepts in materials science and solid mechanics. Focuses on connecting microstructural fracture processes with appropriate macroscopic (continuum) models. Topics: linear elastic and elastic-plastic fracture; fatigue and fatigue crack growth; creep rupture and creep crack growth.
D. M. Parks, R. M. N. Pelloux

2.35 Role of Microstructure in Mechanical Behavior

Prereq.: 2.30
G (1)
3-0-9

Equilibrium and non-equilibrium means of obtaining diverse microstructures in engineering solids. Micromechanisms that govern the deformation and fracture resistance of materials with different microstructures. Discussion of specific examples from prominent industrial alloys, polymers, composites, and cellular solids.
A. S. Argon

Thermodynamics and Statistical Mechanics

2.40 Thermodynamics

Prereq.: 8.02, *18.03*
U (1, 2) SD
4-0-8

Classical thermodynamics emphasizing relation of abstract concepts to physical situations. Work, heat, energy change, and the first law of thermodynamics. Temperature, equilibrium, and reversibility. Introduction to thermodynamics in a computational environment. Thermodynamically coupled systems, second law of thermodynamics, thermodynamic temperature, entropy. Bulk flow and open systems. The pure substance, solid, liquid, and gaseous phases. Applications to engineering systems.
J. L. Smith, Jr., J. B. Heywood

2.41J Thermodynamics of Power Systems

(Same subject as 13.25J)
Prereq.: 2.40
U (2)
3-0-9

Application of thermodynamics to power-generating systems. Thermodynamics of combustion and mixtures of gases. Analysis of Carnot, Rankine, Brayton, Otto, and Diesel cycles. Availability. Performance of modern steam plants, gas turbines, internal combustion engines, refrigeration plants, marine power plants. Economic and pollution aspects. New power generation concepts, such as fuel cells, MHD, vapor engines, solar, wind, tidal.
J. B. Heywood, J. L. Smith, Jr., A. D. Carmichael

2.45J Fundamentals of Energy in Buildings (New)

(Same subject as 1.42J, 4.42J)
Prereq.: 8.02, 18.02
U (1)
3-0-9

Introduction to energy fundamentals important to buildings. Conservation of energy. Properties of pure substances, gas mixtures, psychrometrics. Heat pumps and refrigeration cycles, limiting thermodynamic performance. Heat transfer within buildings and major components.
L. R. Glicksman

2.451J General Thermodynamics I (A)

(Same subject as 22.571J)
Prereq.: Permission of Instructor
G (1)
3-0-9

General foundations of thermodynamics valid for small and large systems, and equilibrium and nonequilibrium states. Definitions of state, property, work, energy, stable equilibrium, available energy, entropy, thermodynamic potential, and interactions other than work (nonwork, heat, mass transfer). Applications to properties of materials, bulk flow, energy conversion, chemical equilibrium, combustion, and industrial manufacturing.
E. P. Gyftopoulos

2.452J Quantum Thermodynamics (A)

(Same Subject as 22.572J)
Prereq.: Permission of Instructor
G (2)
3-0-9

A comparative introduction to the general foundations of classical and quantum mechanics, statistical mechanics, and thermodynamics, pinpointing structural analogies and conceptual differences. Perspectives and open questions on the significance of entropy and irreversibility. A unified quantum theory of mechanics and thermodynamics, including a novel equation of motion for irreversible processes. Examples and applications. Outline of new research opportunities. Self-contained review of necessary mathematical background.
E. P. Gyftopoulos

Heat and Mass Transfer

2.51 Heat and Mass Transfer

Prereq.: 2.20, 2.40
U (1, 2)
3-0-9

Heat conduction in solids; steady and transient states; finned surfaces. Heat and momentum transfer associated with laminar and turbulent flow of fluids in forced and free convection; fully developed flows and boundary layer development in ducts over flat plates and blunt bodies, through tube bundles and packed beds. Condensation. Boiling. Heat exchanger design; heat transfer in nuclear reactors. Radiative heat transfer. Mass transfer in stationary systems; mass transfer associated with laminar and turbulent flows.
B. B. Mikić

2.54 Heat Transfer

Prereq.: —
G (2)
3-0-3

Fundamentals of conduction, radiation of heat, and effects of convection, with applications to problems arising in practice. Primarily for selected officers of US Navy and Coast Guard.
B. B. Mikić

2.55 Advanced Heat Transfer (A)

Prereq.: 2.20, 2.40, 18.075
G (1, S)
3-0-9

Develops similarity between heat, momentum, and mass transfer in forced and buoyancy driven flows. Covers fundamental modes of heat transfer: diffusion, internal and external forced and natural convection, boiling, condensation, and radiative heat transfer. Flow instabilities and heat transfer augmentation techniques. Extends heat transfer results to analogous convective mass transfer processes. Simultaneous heat, momentum, and mass transfer with phase change: liquid-solid and liquid-vapor systems.
B. B. Mikić, S. Motakef

2.56 Conduction Heat Transfer (A)

Prereq.: 2.40, *18.075*
G (2)
3-0-9

Steady and transient-state heat conduction and mass diffusion for various boundary conditions. Solution of differential equations in rectangular, cylindrical, and spherical coordinate systems. Approximate methods: numerical technique, analogies, fixed and floating random walk. Moving boundaries: problems in freezing and melting. Thermal stress resulting from nonuniform temperature distribution. Thermal contact resistance.
B. B. Mikić

2.57J Two-Phase Flow and Boiling Heat Transfer (A)

(Same subject as 22.36J)
Prereq.: 22.312
G (2) **Next offered 1989-90**
3-0-9

See description under subject 22.36J.
W. M. Rohsenow, P. Griffith, M. S. Kazimi

2.58J Radiative Transfer (A)

(Same subject as 10.74J)
Prereq.: 2.51 or 10.302
G (2)
3-0-9

See description under subject 10.74J.
L. R. Glicksman, A. F. Sarofim

Power Systems

2.601J Thermal Power Systems (A)

(Same subject as 13.26J)
Prereq.: 2.20; 2.40 or 2.51
G (2)
3-0-9

Design of thermal power system components and system optimization. Reviews thermodynamics, gas dynamics, and heat transfer. Design of axial and centrifugal compressors and pumps, axial and radial inflow turbines, heat exchangers, evaporators, boilers and condensers. Takes problems and examples from the fields of space, electrical utility, and marine power systems. Assumes knowledge of elementary heat transfer and simple thermal power cycles.
W. M. Rohsenow, A. D. Carmichael

2.615 Internal Combustion Engines (A)

Prereq.: 2.20, 2.40
G (2)
3-0-9

Fundamentals of how the design and operation of internal combustion engines affect their performance and fuel requirements. Study of fuid flow, thermodynamics, combustion, heat transfer and friction phenomena, and fuel properties, relevant to engine power, efficiency, and emissions. Examination of design features and operating characteristics of different types of engines: spark-ignition, diesel, stratified-charge, and mixed-cycle engines. Engine Laboratory project. For graduate and senior undergraduate students.
J. B. Heywood

2.621 Gas Turbine Design (A)

Prereq.: 2.20, 2.40 or 2.41J or 2.51
G (1) **Next offered 1989-90**
3-0-9

Applies engineering science to development of gas turbines. Thermodynamics and fluid mechanics of flow phenomena in turbines and compressors. Design of turbines, compressors, heat exchange, and combustion chambers. Operating characteristics of gas-turbine power plants in various applications. Alternate years.
D. G. Wilson

2.648 Superconducting Magnets (A) (New)

Prereq.: 2.40, 2.51
G (2)
3-0-9

Focuses on one important engineering application of superconductors — generation of large-scale and intense magnetic fields. Physics of superconductivity; review of electromagnetic theory; detailed treatment of magnet design and operational issues,e.g., "usable" superconductors, field and stress analyses, magnet instabilities, ac losses and mechanical disturbances, quench and protection, experimental techniques, cryogenics. New high-temperature superconductors for magnets — design and operational issues at high temperatures.
Y. Iwasa, E. S. Bobrov

2.649 Low-Temperature Refrigeration (A)

Prereq.: 2.40
G (1) **Next offered 1989-90**
3-3-6

Thermodynamic processes for producing low-temperature refrigeration. Problems of heat exchangers, insulation, and rectification. Applications of low-level refrigeration to liquefaction of helium and to application of superconductors. Laboratory projects on related topics according to individual interests.
J. L. Smith, Jr.

2.65J Fluidization (A)

(Same subject as 10.651J)
Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Regimes of fluidizations, slugging, spouted and particulately fluidized beds. Motion of a single bubble in fluidized beds. Bubble behavior and growth in a multi-bubble bed. Properties of circulating fluidized beds. Heat and mass transfer in fluidized beds. Gas-solid reactions. Treatment of particle ensembles. Conversion of gas in bubbling systems. Analyzes non-catalytic gas-solid reactions. Applications to heat exchanges and fluidized-bed combustors.
L. R. Glicksman

Experimental Engineering

2.671 Measurement and Instrumentation

Prereq.: *2.02*
U (1, 2) LAB
2-3-7

Experimental techniques for observation and measurement of fundamental system variables such as force, pressure, temperature, flow, and acceleration. Emphasizes physical principles of transducers, measurement circuitry, and computer-aided methods of data analysis. Typical laboratory experiments involve oscilloscopes, strain gages, accelerometers, thermocouples, digital recorders, etc. Background for lab projects is developed in lectures. Six units may be applied to the General Institute Laboratory Requirement.
C. F. Dewey, Y. Iwasa

2.672 Project Laboratory

Prereq.: *2.20, 2.40,* 2.671
U (1, 2) LAB
1-3-2

Engineering laboratory subject for mechanical engineering juniors and seniors. Major emphasis on interplay between analytical and experimental methods in solution of research and development problems. Communication (written and oral) of results is also a strong component of the course. Groups of two or three students work together on three problems during the term.
S. Motakef, W. Cheng

2.68 Theory and Application of Modern Diagnostics

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-2-4

Introduction to modern techniques for determining the mechanical, thermal, and chemical properties of engineering systems. Principles of operation and applications of instruments such as interferometers, spectrometers, infrared detectors, lasers, chromatographs, nuclear and electron spin detectors, electron and ion microscopes. Theory includes optics, quantum physics, and molecular theory. Computer-based measurement and control introduced. Laboratory project using instruments selected by students. Graduate students only.
W. K. Cheng, J. C. Keck

Design

2.70 Introduction to Design

Prereq.: —
U (1)
2-3-4

Introduces engineering design, stressing creativity and visualization of the design and manufacture process. Instruction is focused on design projects carried out by students working closely with section instructors. Lecture topics range from brainstorming to basic machine elements. Professionalism and designers' responsibility are emphasized throughout the course. Includes a major design-and-build project.
H. West, W. C. Flowers

2.701 Visual Communication in Design

Prereq.: —
U (1, 2)
2-2-2

Lectures and laboratory sessions on the basics of manual and computer-aided sketching and drawing to delineate engineering design information and data. Exercises focus on spatial visualization, pictorial representation, orthographic projection, sectional and auxiliary views, descriptive geometry, dimensioning, and tolerancing.
W. C. Flowers, J. B. Grinnell, Jr.

2.72 Elements of Mechanical Design

Prereq.: 2.01, 2.70
U (1)
3-3-6

Examination and practice in the application of many mechanical design elements, including control components. Students working in groups will design, fabricate, and test prototype devices in response to requests from industrial sponsors. Topics: typical machine elements, power transmission elements, motors and prime movers, control elements, material selection, and assembly techniques. Taken prior to 2.73, this subject enhances the design experience in the latter.
C. R. Peterson

2.73 Design Projects

Prereq.: *2.03J*, 2.20, 2.30, 2.40, 2.70
U (2)
2-3-4

Practice in engineering design through projects specifically chosen to integrate significant portions of material covered in prerequisites. Typically, one group project and two individual projects. Emphasizes pursuing creative solutions to current, real, engineering design problems. Guest lecturers invited to provide problem backgrounds and insights. Other lecturers address the breadth of topics involved in engineering design from analytical techniques to human-machine interactions, economics, and patent laws.
C. R. Peterson

2.731 Advanced Engineering Design (A)

Prereq.: 2.73
G (1)
3-3-6

Two sections: 1) Involves advanced topics in engineering design: optimization, kinematics, and mechanics, human factors engineering, and idea generation and creative problem solving. 2) As ongoing case studies of the design process, students design, build, and test pieces of mechanical hardware for industrial clients. Requires two semesters for design, assembly, and "debugging" of the mechanical devices. During the fall, defines problems, creates and evaluates solutions, and generates a detailed design. Graduate status or permission of instructor.
W. P. Seering

2.732 Advanced Design Projects (A)

Prereq.: 2.731
G (2)
3-0-6

Continuation of 2.731. Includes discussions of such topics as applications of microprocessors, product liability and safety, entrepreneurship, marketing of a product, patent applications, and methods of redesign. From parts built for them by participating industrial clients, students assemble and "debug" devices that they designed during term 1 in 2.731. By the end of term, devices are brought to specification and presented to the respective sponsors. Permission of instructor required.
W. P. Seering

2.737 Designing Smart Machines (A)

Prereq.: 2.10, 2.73, or equivalents
G (1)
2-4-6

Introduction to designing smart products with embedded microcomputers. Topics include microprocessors as design elements, microprocessor architecture, interfacing to mechanical devices, assembly and high-level languages, design of real-time software, hardware/ software trade-offs, implementation choices for smart products, smart product design process. Students undertake one or more preliminary projects and a substantial term design project completed individually or in groups. Limited enrollment. Permission of instructor required.
W. K. Durfee

2.741 Fundamentals of Mining Technology (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Essential features of mining operations, beginning with the nature and origins of orebodies, properties of materials, and a study of the geometry of mining in general. Safety and environmental considerations, including regulations for gassy mines. Study of force and energy requirements of basic excavation and fragmentation elements. Application of basic information to design and/or evaluation of innovative mining concepts. Study of potential for interplay between mining geometry and equipment design in development of new methods. Alternate years.
C. R. Peterson

Biomedical Engineering

(See also 2.277, 2.900J, and 2.907)

2.75 Physiology and Biomechanics of Human Movement (A)

Prereq.: Permission of Instructor
G (1)
3-3-6

Synergistic study of anatomy-physiology and biomechanics of human movement. Human sensory, nervous, muscular, and skeletal systems and their integration as they relate to posture, gait, and manipulation. Biomechanics of muscle, bone, and skeletal joints. Human performance measurement and sports biomechanics. Focus on normal human system leads to pathological conditions and to technological responses, i.e., amputation prosthesis, arthroidial joint deterioration and replacement.
R. W. Mann

2.76J Ultrasound: Physics Biophysics, and Technology (A)

(Same subject as 6.562J, HST 530J)
Prereq.: Permission of Instructor
G (1) **Not to be offered 1989-90**
4-1-7

Physics and technology of generation and detection of ultrasound. Transducers and arrays. Propagation and fields. Diagnostic, therapeutic, and processing applications in medicine and industry. State of the art of imaging and Doppler systems. Biophysics, biological effects, linear and nonlinear phenomena. Hazards and safety levels.
P. P. Lele, F. R. Morgenthaler

2.761J Principles of Medical Imaging (A)

(Same subject as 22.56J HST 561J)
Prereq.: Permission of Instructor
G (1)
4-0-8

See description under subject 22.56J.
P. P. Lele, V. Wedeen

2.762J Laser, Microwaves, Ultraviolet, Magnetic Fields, and Ultrasound in Biomedical Sciences (A)

(Same subject as HST 531J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
4-1-7

Fundamental physics and biophysics, biological effects and mechanisms, hazards and safety levels of laser, microwaves, magnetic fields. Ultrasound and ultraviolet. Special emphasis on current techniques and applications in medicine and biomedical research.
P. P. Lele, Staff

2.77 Research in Biological Effects and Applications of Ultrasound and Other Non-Ionizing Radiations (A)

Prereq.: 2.76J
G (1, 2)
Arr.

Opportunity for graduate students and advanced undergraduates to pursue substantial theoretical or practical projects of their own choice or to conduct critical analysis of literature in this area. Details arranged on an individual basis.
P. P. Lele

2.78 Seminar on Rehabilitation Engineering Research and Practice

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

A seminar for graduates and undergraduates providing a contemporary overview of research, professional roles, and conceptual framework in application of engineering to rehabilitation medicine and underlying pathophysiology. A critical review paper and presentation related to a seminar topic required. Lecturers include authorities from the Boston area: MIT and Harvard Medical School faculty, members of the international research community, students conducting research, and participants in the seminar series.
M. J. Rosen, R. W. Mann

2.781J Biomedical Instrumentation Electronics

(Same subject as 16.608J, HST 570J)
Prereq.: Permission of Instructor
G (S)
6-6-6

See description under subject HST 570J.
D. Rowell, S. K. Burns

2.791J Quantitative Physiology: Cells and Tissues

(Same subject as 6.021J, HST 541J)
Prereq.: 2.02 or 6.002 or 6.071; 8.02; 18.03
U (1)
4-2-6

See description under subject 6.021J.
I. V. Yannas, T. F. Weiss, R. C. Lee

2.792J Quantitative Physiology: Organ Transport Systems

(Same subject as 6.022J, HST 542J)
Prereq.: *2.791J;* 2.20 or 6.013
U (1)
3-2-7

See description under subject 6.022J.
R. D. Kamm, R. G. Mark

2.793J Quantitative Physiology: Sensory and Motor Systems

(Same subject as 6.023J, 16.351J, HST 543J)
Prereq.: 2.02 or 6.003 or 16.30
U (2)
3-2-7

See description under subject 6.023J.
R. W. Mann, L. S. Frishkopf, L. R. Young

Manufacturing

(See also 2.922)

2.800 Tribology (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Geometric, chemical, and physical characterization of surfaces. Various theories of friction and wear of metals, polymers, and ceramics. Special emphasis on delamination theory, discussion of erosion, boundary lubrication and solid-film lubrication. Rolling contact problems. Tribological problems in magnetic recording and electrical contacts. Monitoring and diagnosis of friction and wear. Case studies.
E. Rabinowicz, N. Suh

2.810 Analysis of Manufacturing Processes (New)

Prereq.: 2.01, 2.20
G (2)
3-0-9

Unified introduction and treatment of manufacturing processes used to make mechanical and microelectronic devices. In-depth analysis of basic subtractive, additive, and forming processes by the principles of mechanics, heat and mass transfer, thermodynamics, and chemistry. Course will emphasize such issues as quality of the output, production rate, microstructural effects, equipment requirements, and cost. This broad treatment will include applications to the processing of metals, polymers, composites, and ceramics.
T. G. Gutowski, G. Chryssolouris, E. Sachs

2.820J Polymer Processing (A)

(Same subject as 3.94J)
Prereq.: 10.301 or 2.20
G (2)
3-0-9

Reviews physicochemical, mechanical, and rheological properties of polymers. Surveys processing techniques. Modeling, analysis, and scale-up of extrusions, molding, thermoforming, calendering, and mixing. Case studies in process syntheses. Relationship between selected processing techniques and properties of end products. Limitations of the present state of the art. Assigned projects.
T. G. Gutowski, D. K. Roylance

2.822 Processing of Polymeric Composites (A)

Prereq.: 2.01, 2.20
G (1)
3-0-9

Scientific and engineering aspects of manufacturing with polymeric composite materials. Effects of processing on mechanical performance, interfaces, rheological behavior of polymers and reactive systems. Modeling of processing steps including forming, flow and mold filling, fiber orientation and breakage, consolidation, cure, solidification, and bonding. Discussion and models taken from major processing technologies. Topics in automation and new and innovative processes.
T. G. Gutowski

2.830 Control of Manufacturing Processes (A)

Prereq.: 2.14
G (2)
3-0-9

Develops general concepts for modeling and control of manufacturing processes. A brief review of classical and discrete system design methods is followed by detailed treatment of the position servo problem. Modeling and control problems associated with a variety of processes are then studied. These include cutting, forming, welding, and casting of metals and polymers.
D. E. Hardt

2.835 Robot Design and Control (A)

Prereq.: 2.05, 2.151
G (2)
3-0-9

Graduate subject on the analysis, design, and control of robot manipulators. Geometry, kinematics, statics, and dynamics of manipulators. Sensors and actuators, arm design. Position and trajectory control, compliant motion control. Robustness and adaptation in robot control, modeling performance trade-offs.
J-J. E. Slotine, K. Youcef-Toumi

2.845 Nondestructive Evaluation and Quality Engineering (A)

Prereq.: Permission of Instructor
G (2)
3-3-6

Principles and applications of nondestructive techniques for materials evaluation, with emphasis on physics, signal processing, and interpretation. Relation to manufacturing quality assurance tools, statistical quality control, in-process sensing, and automation. Life testing considerations including reliability, accelerated testing, proof testing, and failure analysis. Laboratory projects.
M-K. Tse, E. Rabinowicz

2.850 Machine Tools and Manufacturing Systems (A)

Prereq.: Permission of Instructor
G (1)
3-3-6

Machine tool basic building principles. Computational methods for machine tool elements. Machine tool quality. Machine tool automation. Numerical control and positioning systems. Adaptive control and flexible manufacturing systems. Process planning and scheduling related to machine tools. Future concepts in the machine tool technology.
G. Chryssolouris

2.852 Manufacturing Systems Analysis (A) (New)

Prereq.: —
G (2)
3-0-9

Models of manufacturing systems, including transfer lines and flexible manufacturing systems. Calculation of performance measures, including throughput, in-process inventory, and meeting production commitments. Real-time control of scheduling. Effects of machine failure, set-ups, and other disruptions on system performance.
S. B. Gershwin

2.86 Manufacturing Processes and Systems

Prereq.: —
U (1, 2) LAB
3-3-3

Introduction to modern manufacturing processes for metals, polymers, ceramics, and composite materials. Discussions on manufacturing systems, automation technology, design and manufacturing integration, computer applications, and principles and techniques for quality assurance. Lectures emphasize process modeling and analysis, while laboratory encompasses both hands-on practice and engineering experimentation. Six units may be applied to the General Institute Laboratory Requirement.
E. Sachs, T. G. Gutowski, G. Chryssolouris, M-K. Tse

2.870 Development Process for Products and Manufacturing (A) (New)

Prereq.: Permission of Instructor
G (1)
3-3-6

Total development process that begins with strategic needs and concludes with the new product in production. Topics include product requirements, concept generation and selection, design, product optimization, tolerances, prototype development, design for manufacturability, process optimization, on-line quality control, and holistic management. Emphasizes methods that are improvements over common recent industrial practice, integrated into the complete process that covers all major aspects of bringing new products into being.
D. Clausing

2.881 Artificial Intelligence in Design and Manufacturing (A) (New)

Prereq.: 1.00, 2.10, or 6.001
G (1)
2-0-7

Applications of artificial intelligence to manufacturing, ranging from design to production. Principles, strengths, and limitations of existing techniques as well as present and future applications. Topics include knowledge representation issues and techniques, prolog, expert systems, machine learning, and application areas. These are covered in two concurrent tracks — knowledge engineering and logic programming.
S. H. Kim

2.882 Axiomatic Design of Manufacturing Processes and Products (A) (New)

Prereq.: 2.01, 2.20, 2.30, 2.40
G (2)
3-0-9

Introduction to design and design processes; introduction to design axioms, corollaries, and theorems; mathematical representation of design: formulation of design matrix; analysis of functional independence; graphical representation of functional independence; measure of information content; application to process planning; case studies involving real industrial problems; use of predicate logic and prolog in axiomatic design.
N. P. Suh

Polymers and Fibers

2.900 Biomedical Materials

Prereq.: 3.091 or 7.01
U (2)
2-0-4

Science and engineering of materials used in medical applications: orthopedic implants, artificial joints, blood vessel replacements, artificial organs. Structure and properties of polymers, ceramics, and metals on interaction with the human body. Histological analysis of connective tissue on materials science and engineering. Fracture, structure, healing of normal and abnormal bone. Implantation problems: inflammation, thrombogenesis, rejection, resorption, corrosion.
I. V. Yannas

2.907J Physical Chemistry of Condensed Biological States (A)

(Same subject as 3.95J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Analysis of molecular structure and of macromolecular interactions in extracellular matrices and connective tissues. Configurations of macromolecules. Solid-state physics of collagen, elastin, and glycosaminoglycans. Bonding and nonbonding interactions between macromolecules in extracellular matrices. Fiber-matrix interactions in tendon, skin, cartilage, and the blood vessel wall. Mechanics of mineralized (bone) and nonmineralized connective tissues.
I. V. Yannas

2.921J Polymer Deformation and Fracture (A)

(Same subject as 3.951J)
Prereq.: 2.30
G (1)
3-0-9

Linear and nonlinear viscoelasticity below and above T_g. Phenomenology of plastic deformation in crystalline, and glassy polymers, molecular theories for yielding, post yield extensions for intermediate and large strains, development of deformation textures, anisotropic yield conditions. Fracture in polymers, statistical damage accumulation. Crazing as a precursor to fracture, kinetics of nucleation of crazes, mechanics of craze extension, development and propagation of cracks. Fatigue in polymers under both static and cyclic loading.
I. V. Yannas

2.922 Fiber Processing Mechanics (A)

Prereq.: 2.01 or 3.11
G (2) **Next offered 1989-90**
3-0-9

Analysis of mechanical processes used to convert natural or synthetic fibers into useable forms such as bonded, twisted, woven, knitted, stitched, or tufted materials. Review of mechanical principles of textile technological processes used in fiber-producing, textile, and apparel industries. Focus on mechanics of selected processes such as drafting, twisting, texturing, weaving, and knitting. Treatment of material-process interactions in steady state and during transient operation. Effect of process variables on product quality and performance.
S. Backer

2.924 Structural Mechanics of Fiber Assemblies (A)

Prereq.: 2.01 or 3.11
G (2) **Next offered 1989-90**
3-0-9

Interaction between the mechanical properties of polymeric fibers and their statistical variation, and the geometric configurations of fiber assemblies. Differential geometric models of twisted structures and of woven, knitted, and stitched materials. Consideration of influence of textile manufacturing process on local deviations from ideal geometry and their significance in product performance. Analysis of mechanical behavior as in tensile load- deformation, fabric tearing, abrasion, drape, pucker, curl, shear, yarn slippage, buckling, bending, and seam failure.
S. Backer

2.93J Engineers, Scientists, and Public Controversies (New — Context Subject)

(Same subject as 8.206J and STS 012J)
U (2)
3-0-9

Investigates the nature of controversies surrounding science and technology, and the roles technical specialists play in their resolution. Students analyze the technical, social, political, and ethical context of public controversies through case studies documented by archival videotapes, readings, and testimony of guests. Cases may include the space shuttle accident, nuclear reactor safety, Star Wars, AIDS and other medical testing, and the release of environmental contaminants. May *not* count toward HASS Requirement.
J. A. Fay, B. T. Feld, C. Weiner

Special Studies

2.94J Accounting for the Social Consequences of Technological Change (New—Context Subject)

(Same subject as 14.15J)
Prereq.: 14.01, 14.02, and 14.02; 2.70; and for engineering majors, 2.40
U (2)
2-0-7

Examines various indirect effects of technological change on work, health, lifestyle, environment, etc. Three case studies chosen by class. Teams of students identify and evaluate indirect costs and benefits. Teams propose methods to take these into account in decision making via government regulatory or tax intervention or private voluntary action. Intended for juniors and seniors with engineering and economics training. May **not** count toward HASS Requirement.
D. G. Wilson, J. Rothenberg

2.941J Invention

(Same subject as 16.671J)
Prereq.: Permission of Instructor
G (1)
3-0-6

Analyzes invention process. Presents methodology for invention. Topics: 1) observing technology; 2) analyzing needs; 3) indentifying critical parameters to trigger potential solutions; 4) creative synthesis based on key parameters. Also patents, licensing, and marketing. Requires term project. Students work on inventing to meet needs of their own choice as well as those from companies belonging to the Innovation Center's industry program.
W. C. Flowers, A. D. Carmichael, W. R. Markey

2.942 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult

2.943 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

2.944 Product Design

Prereq.: —
G (2)
3-1-5

Project-centered subject addressing transformation of new ideas into technology-based products, attaining a proper match between product and marketplace, from the perspective of both source and customer. Product design issues: evaluation; market perception; aesthetics and human interfacing; design for manufacturability, reliability, and repairability; pricing and legal implications.
W. C. Flowers

2.951 Engineering Internship

Prereq.: —
U (1, 2, S) [P/F]
0-6-0

2.952 Advanced Engineering Internship (A)

Prereq.: 2.951
G (1, 2, S) [P/F]
0-6-0

Provides academic credit for undergraduate and graduate work assignments for Mechanical Engineering students participating in the Engineering Internship Program. Undergraduate participation is approximately six months over two summers of practical work in manufacturing, engineering, research and development at an industrial plant. Graduate participation by students admitted to the Department's graduate program consists of approximately seven months at industrial plant. Credit is awarded after evaluation and approval of the actual work performed.
I. Paul

2.96 Management in Engineering

Prereq.: —
U (1)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult, H. S. Marcus

2.97 Independent Activities

Prereq.: —
U (J)
Arr.

For undergraduates desiring to carry on independent studies during the January Independent Activities Period. Each student will carry on a program of his or her own choosing, either as an independent worker, or as a member of a team or class. Special lectures, seminars, and laboratory projects arranged when appropriate. Programs arranged on an individual basis in consultation with the Instructor. Credit arranged with the coordinator: D. G. Wilson.

2.995 Special Topics in Mechanical Engineering

Prereq.: —
U (1, 2, S)
Arr.

For undergraduates desiring to carry on substantial projects of own choosing in mechanical engineering. Work may be of experimental, theoretical, or design nature. Projects may be arranged individually in most fields of department interest, i.e., in mechanics and materials, thermal and fluid sciences, systems and design, and biomedical engineering.
Coordinator: D. G. Wilson.

2.996 Advanced Topics in Mechanical Engineering (A)

Prereq.: —
G (1, 2, S)
Arr.

Assigned reading and special problems or research in special areas, either theoretical or experimental, or design. Arranged on individual basis with instructor in the following areas: mechanics and materials, thermal and fluid sciences, systems and design, and biomedical engineering. Coordinator: A. A. Sonin.

2.998 Introduction to Technology and Law

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. D. Nyhart

2.999 Engineer's Degree Thesis Proposal Preparation (A)

Prereq.: —
G (1, 2, S)
Arr.

For students who must do additional work to convert an S.M. Thesis to an M.E. Thesis, or for students who do an M.E. Thesis after having received an S.M. degree.
A. A. Sonin

Course 3 Materials Science and Engineering

3.UR Undergraduate Research

Prereq.: —
U (1, 2, S) [P/F]
Arr.

Extended participation in work of a research group. Includes independent study of literature, direct involvement in group's research (commensurate with student skills), and project work under an individual faculty member. See UROP coordinator for registration procedures.
S. B. Brown

3.00 Thermodynamics of Materials

Prereq.: 18.02
U (1) SD
4-0-8

Essential features of first, second, and third laws of thermodynamics and their application to materials. Statistical interpretation of entropy. Experimental techniques used to measure thermodynamic functions. Introduces phase diagrams, phase rule, and thermodynamics of solutions. Thermochemistry of homogeneous and heterogeneous reactions.
T. W. Eagar

3.01 Physical Chemistry of Materials

Prereq.: 3.00 or 5.60 or 2.40 or 10.13
U (2)
4-0-8

Reactions involving pure condensed phases and gaseous phase, behavior of solutions, free energy-composition and phase diagrams of binary and ternary systems, reaction equilibria in systems containing components in condensed solution. Electrochemistry, corrosion, Gibbs phase rule, chemical kinetics, elementary mechanisms, reaction rate constant, activation energy, surface tension.
G. J. Yurek

3.02 Crystal Defects and Phase Transformations

Prereq.: 3.01 or 10.14, 3.13
U (1)
3-0-6

Dislocation properties and interactions; plastic flow; structure of interfaces; nucleation in liquids and solids; solid-state transformations, including diffusional transformations, massive transformations, and martensites; solidification.
A. Mortensen

3.03 Chemical Metallurgy

Prereq.: 3.185
U (2)
3-0-6

Chemical principles of extractive metallurgy. Representations of heterogeneous equilibria. Unit operations and processes. Roasting of sulphides. Gaseous reduction of iron oxide. Reduction of zinc oxide and ferroalloy oxides. Reduction of halides. Smelting of iron ores, matte smelting of copper ores. Refining processes-gas-liquid, solid-liquid, and liquid-liquid. Hydrometallurgy and electrometallurgy. Kinetics of high-temperature processes. Examples taken from industrial processes.
D. K. Roylance

3.04 Special Problems in Materials Science and Engineering

Prereq.: —
U (1, 2, S)
Arr.

For undergraduates desiring to carry on projects of their own choosing, which may be experimental, theoretical, or of a design nature. Also for undergraduate studies arranged by students or staff, which may consist of seminars, assigned reading, or laboratory projects. See Chairman of Undergraduate Committee for registration procedures.
D. K. Roylance

3.041 Thesis Seminar

Prereq.: —
U (1, 2)
Arr.

Lectures on basic skills necessary for conducting thesis planning, research, analysis, and preparation of final document. Included: library resources, how to plan experiments, departmental central facilities, laboratory safety, data analysis, technical writing, and thesis format. Seminar also requires that each student present an initial oral research proposal and deliver a lecture reporting on completed thesis. Must be taken both terms to receive 3 units of credit.
D. K. Roylance

3.05 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

3.06 Glass Science and Engineering

Prereq.: 3.01 or 10.14, 3.13
U (2)
3-0-6

Glass structure and microstructure and its relation to processing and properties. Attention to glass formation, phase separation, color, viscous flow and relaxation, glass melting and forming. Consideration of applications such as glass-ceramic materials, fast-ion conducting glasses, optical waveguides, and glass matrix composites. Emphasizes recent developments and the present state of the particular technologies, including discussion of the relevant patent literature.
Y.-M. Chiang

3.062 Polymer Chemistry

Prereq.: 3.091 or 5.11
U (1)
3-0-6

Preparation of polymeric materials and their characterization. Topics: fundamentals of chain and step growth polymerization, chemistry of organic radicals and ions, synthesis-structure-property relationships, and use of modern techniques for determination of polymer composition, molecular weight, and microstructure.
M. F. Rubner

3.063 Polymer Physics

Prereq.: 3.062, 3.00
U (2)
3-0-6

Principles underlying the physics and physical chemistry of polymers in solution and in the solid state. Topics include conformation and molecular dimensions of polymer chains; thermodynamics of polymer solutions; an examination of the glassy, crystalline, and rubbery elastic states of polymers; kinetics and thermodynamics of crystallization; liquid crystallinity in polymers; thermodynamics of rubber elasticity. The electrical, optical, transport, and mechanical properties of polymers are analyzed with respect to the above topics.
M. F. Rubner

3.064 Polymer Engineering

Prereq.: 3.062, 3.11, 3.185
U (1)
3-0-6

Quantitative models for engineering analysis and design as applied to polymers. Includes linear and nonlinear viscoelasticity, yield models, homogeneous and flaw models for fracture and fatigue, rheological properties of polymer fluids, governing equations for thermomechanical fluid processing, and models for industrially important processing methods.
D. K. Roylance

3.065 Polymer Science Laboratory

Prereq.: 3.081, 3.11
U (1)
1-8-3

Synthesis and molecular characterization of polymers. Condensation polymerization and chain reaction polymerization and copolymerization, reactions in homogeneous phase and at interfaces, and the synthesis of linear chains and highly ramified structures are carried out. The resulting macromolecules are characterized: molecular mass and its distribution by several methods, composition and constitution by spectrometric and other analytical means, and molecular thermodynamic properties. Polymer-analogous reactions are used to modify macromolecules.
M. F. Rubner

3.069 Ceramics Processing

Prereq.: 3.07, 3.185
U (2)
3-0-6

In-depth study of the unit operations in processing technical ceramics and the effect of these operations on the properties of the sintered material. Topics include powder production and conditioning, drying, forming, sintering, and microstructure development. Relevant aspects of transport phenomena, colloid science, and chemistry are discussed, as well as contemporary issues in ceramic composite processing. Case studies involving both electronic and structural ceramics are reviewed.
M. J. Cima

3.07 Introduction to Ceramics

Prereq.: 3.01 or 10.14, 3.13
U (1) SD
3-0-6

Introduces hierarchy of structures and their effects on properties in oxide and non-oxide ceramics and glasses. Presents crystalline structures and their relation to physical properties relevant in structural and electronic uses of ceramics. Discusses defects and their role in controlling certain physical properties. Applies phase equilibria, interface properties, atomic mobility and phase transformations to development of structure at various scales. Individual study of a particular ceramic, ceramic property, or ceramic process selected by the student is required.
Y.-M. Chiang

3.070J Materials for Nuclear Applications

(Same subject as 22.070J)
Prereq.: 3.091
U (2)
3-0-9

See description under subject 22.070J.
R. G. Ballinger

3.075 Ceramics and Glass Laboratory

Prereq.: 3.081, 3.06 or 3.07
U (1)
2-7-3

Investigates ceramics and glass properties and processing by means of a series of laboratory experiments, plus an intensive independent project undertaken with faculty supervision. Experiments include monodisperse ceramic powder synthesis, zinc oxide varistors and barium titanate thermistors, high-performance structural ceramic properties, glass-ceramics composition, and processing analysis of ceramic microstructures with electron microscopy. Limited enrollment. Permission of instructor required.
M. J. Cima

3.08J Industrial Competition in the US and Asia
(New — Context Subject)

(Same subject as 21.464J)
Prereq.: —
U (2)
3-0-6

Examines causes of economic efficiency and international efficiency and international competitiveness in economies of the US and Asia, particularly China and Japan, considering relative importance of technological, economical, social, and historical factors. Topics include costs of production, product quality, organizational structures, labor relations, and the educational system. Case studies of selected industries such as automotive, steel, electronics, computers, and biotechnology. May *not* count toward HASS Requirement.
J. P. Clark, P. C. Perdue

3.081 Materials Laboratory

Prereq.: Permission of Instructor
U (1, 2) LAB
2-6-7

Introduces study of materials by light, X-rays, and electrons. Examines microstructures and investigates relationship of structure to mode of fabrication. Applies classical techniques of light microscopy and X-ray diffraction and the modern analytical tools of transmission and scanning electron microscopy. Limited enrollment.
L. W. Hobbs

3.082 Metals Processing Laboratory

Prereq.: 3.01, 3.081, 3.13
U (2)
1-6-5

Introduces relationship between processing-structure-properties and performance of materials. Each student participates in three laboratory experiments drawn from metals processing. Includes instruction in safety, technical writing, oral presentation, and experimental design.
R. G. Ballinger, R. M. Pelloux

3.091 Introduction to Solid-State Chemistry

Prereq.: —
U (1, 2) SD
5-0-7

Development of relationships between electronic structure of elements, bonding characteristics, and crystal structure. Characterization of atomic and molecular arrangements in crystalline solids. Mechanisms and energy changes in chemical reactions and phase transformations. Chemical and physical properties of solids — metals, semiconductors, insulators, glasses, and polymers — as they relate to basic atomic parameters and processing technology.
R. M. Latanision, A. F. Witt

3.092 Higher, Faster, Hotter, Cheaper: Limits to Performance
(New)

Prereq.: 8.01, and 3.091 or 5.11
U (2)
2-0-4

Exploration of physical and economic limits to performance of engineering systems imposed by properties and costs of currently available materials. Discusses why materials behave as they do, based on physical and chemical principles, and what can be done to improve their desired characteristics. Examples are drawn from design of autos, high performance aircraft (both high speed and low weight), biomechanical devices, space vehicles, space power systems, sports equipment, superconducting devices, communications equipment, and computers.
D. V. Ragone

3.094 Materials Technology

Prereq.: —
U (2)
3-0-9

Mechanical behavior, phase diagrams, microstructures, and phase transformations in steels, aluminum alloys, and titanium alloys used in aerospace, automotive, and ocean vehicles. Influence of microstructure and environment on fatigue and fracture behavior. Concepts and applications of fracture mechanics. Overview of polymers, composites, and ceramics used in vehicles.
J. B. Brown

3.10 Chemical Physics of Materials

Prereq.: 3.13, 18.03
U (2) SD
4-0-8

Introduction to quantum physics of electronic structure and chemical bonding of atoms, molecules, and solids. Emphasis on those concepts that are basic to an understanding of the chemical and physical properties of materials. Topics: wave mechanics and Schroedinger's equation; atomic and molecular orbitals; the nature of the chemical bond; electronic structure of semiconductors and insulators; electronic structure of metals and alloys.
R. M. Rose

3.11 Mechanics of Materials

Prereq.: 8.01, 18.02
U (2) SD
4-0-8

Response to materials to applied loads: concepts of stress and strain, governing equations for stress analysis problems, coordinate transformation of stresses and other tensors, energy methods, the finite element method, linear elastic fracture mechanics, photoelasticity and other experimental techniques, yield criteria, mechanics of anisotropic media and composites, design of simple structures (trusses, torsion rods, beams, pressure vessels). Computer exercises.
D. K. Roylance

3.13 Structure of Solids

Prereq.: 8.02
U (1)
4-0-8

Uses symmetry theory in the description of the atomic arrangement in crystals. Derivation of space lattices, point groups, crystal systems, and plane groups. Principles of space group derivation and equivalent positions and their use in specifying structure. Interprets structures in terms of packing and coordination polyhedra. The nature of imperfections in real materials: point defects and the structure of line and planar defects.
S. M. Allen

3.14 Physical Metallurgy

Prereq.: 3.02
U (2)
3-0-6

Relationship between structure and properties of engineering alloys presented and discussed in detail. Alloy systems covered include steels, stainless steels, aluminum and titanium alloys, and superalloys. Processing, microstructure, and properties of each alloy system illustrated by case studies.
N. J. Grant, R. M. Pelloux

3.143J Materials of Construction

(Same subject as 1.59J)
Prereq.: 8.01
U (2) SD
3-0-9

See description under subject 1.59J.
F. J. McGarry, F. Moavenzadeh

3.15 Electrical, Optical, and Magnetic Materials and Devices

Prereq.: *3.10*
U (1)
3-0-6

Electronic, optical, and magnetic properties of materials in terms of electronic structure, chemical composition, and bonding. Properties of metals, semiconductors, and insulators including electrical conduction, thermoelectric power, Hall effect, optical absorption and reflection, luminescence, magnetism related to microstructure, impurities, and degree of disorder. Manipulation of properties for incorporation into devices.
H. L. Tuller

3.155J Microelectronics Processing Technology

(Same subject as 6.701J, 10.611J)
Prereq.: 3.15
U (1, 2)
3-4-5

See description under subject 6.701J.
D. A. Rudman, C. V. Thompson, D. J. Edell, H. H. Sawin, C. G. Sodini

3.156 Electronic Materials Project Laboratory

Prereq.: 3.155J
U (2)
1-6-2

Student use of facilities of Microelectronics Laboratory for individual or team projects. Projects illustrate processing-structure-properties relationships in electronic materials. Students participate in choice and design of projects that include fabrication and characterization phases.
C. V. Thompson

3.16 Electronic Materials (Revised Content)

Prereq.: 3.15, 3.155J
U (2)
3-0-6

Synthesis of semiconductor physics and fabrication concepts. Evaluation of real semiconducting systems, i.e., IV, III-V, II-VI type compounds in relation to their crystal, energy band and defect structure and transport properties. Implications for junction fabrication and properties including p-n, Schottky, and MOS junctions. Analysis of other interfaces of particular interest to the materials technologist such as electrically active grain boundaries and surfaces.
H. C. Gatos

3.17J History and Anthropology of Materials Technology

(Same subject as 21.543J)
Prereq.: —
U (1) HASS **Next offered 1989-90**
3-0-6

Evaluates development of several major materials technologies and their impact on preindustrial societies. Considers criteria societies use when selecting and processing materials and why people engineer certain properties of materials to exclusion of others. Explores ideological and aesthetic criteria and social values so often overwhelmingly influential in materials development. Meets with 3.79. Research term project required for graduate credit.
L. W. Hobbs, H. N. Lechtman

3.172 Inventions and Patents

Prereq.: 14.02
U (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. H. Rines

3.185 Transport Phenomena in Materials Engineering

Prereq.: 3.01, 18.03
U (1)
4-0-8

Definition of viscosity, simple overall mechanical energy balances, elements of laminar flow and turbulent flow. Thermal conductivity, steady and unsteady conduction problems, forced and natural convection, heat transfer coefficient, and radiative heat transfer. Definition of binary diffusivity, convection mass transfer, and mass transfer coefficient. Illustrative examples given throughout, chosen from the materials processing field.
J. Szekely

3.20 Thermodynamics of Materials (A)

Prereq.: 3.01
G (1)
4-0-8

Offers advanced treatment of thermodynamic properties of inorganic materials, including introductory statistical thermodynamics and surface thermodynamics. Applies laws of thermodynamics to chemical behavior of elements, compounds, and solutions. Discusses heterogeneous equilibria, chemical reactions, and thermodynamics of interfaces and structural defects.
G. Kalonji

3.21 Kinetic Processes in Materials (A)

Prereq.: 3.185
G (2)
4-0-8

Presents unified treatment of kinetics from phenomenological and atomistic viewpoints. Covers diffusion in metals and non-metals, chemical kinetics, and kinetics of phase transformations, including nucleation, growth, coarsening, and spinodal decomposition. Also includes non-catalytic gas-solid reactions and oxidation of metals and alloys.
D. R. Sadoway

3.25J Physics of Inelastic Deformation of Solids (A)

(Same subject as 2.302J)
Prereq.: 2.30 or 2.301
G (2) **Not to be offered 1989-90**
3-0-9

See description under subject 2.302J.
A. S. Argon

3.26J Micro Mechanisms of Fracture (A)

(Same subject as 2.303J)
Prereq.: 2.30 or 2.301
G (2) **Next offered 1989-90**
3-0-9

See description under subject 2.303J.
A. S. Argon

3.271 Structure of Materials (A)

Prereq.: 18.03, 3.10
G (1)
4-0-8

Quantitative description of atomic arrangements in selected metals, oxides, and silicates important in materials science. Interprets structures in terms of coordination polyhedra and packing. Relationships between structures: polymorphism, polytypism, and derivative structures. Describes diffraction using Fourier transforms and series. Determines structure through diffraction effects: the phase problem, Patterson function, and direct methods for phase determination.
B. J. Wuensch

3.29 Special Problems in Materials Science (A)

Prereq.: —
G (1, 2, S)
Arr.

Advanced work in the field for qualified students. Course work involves lectures, conferences, assigned readings, or supervised laboratory work.
L. W. Hobbs

3.30 Electron Microscopy: Image Interpretation (A)

Prereq.: 3.081, 3.13
G (2)
3-2-7

Derives relationship between detail in transmission electron microscopy images and internal structure of an object to the atomic level. Fourier theory of diffraction. Lens action, aberrations, and transfer functions. Elastic and inelastic interaction of electrons with atoms. Kinematical and dynamical theories of electron diffraction. Phase object approximations and high-resolution imaging methods. Imaging of defects with displacement and replacement fields. Laboratory sessions.
L. W. Hobbs

3.31 Phase Transformations (A)

Prereq.: 3.20, 3.21
G (2)
3-0-9

Advanced treatment of phase transformations in solids. Homogeneous and heterogeneous nucleation. Theories of thermally activated growth processes and morphological stability. Transformation by spinodal decomposition and continuous ordering. Transformation mechanisms in systems with multicritical points. Eutectoidal transformations and cellular precipitation. Crystallographic theory and mechanisms of martensitic transformations.
S. M Allen

3.32 Introduction to Electron Optical Instruments (A)

Prereq.: 3.13, 3.14
G (1) **Next offered 1989-90**
2-4-6

Treats interaction of electrons with materials in detail. Describes modern scientific tools employing results of these interactions to obtain information about structure and chemistry of materials on a microscale. Techniques: electron microanalysis,Auger spectrometry, scanning and transmission electron microscopy, low-energy electron diffraction, and field ion microscopy.
J. B. Vander Sande

3.33 Defects in Crystals (A)

Prereq.: 3.02, 3.12
G (2)
3-0-9

Unified treatment of point, line, and planar defects in crystals. Point defects include vacancies, self-interstitials, and solute atoms. Line defects include dislocations. Planar defects include stacking faults, small- and large-angle grain boundaries, and interphase boundaries. Discusses geometrical structure and physical properties such as stress fields, energies, and mobilities. Treats interactions between defects including point defect clustering, point defect-dislocation pinning, dislocation climb, and grain boundaries as point defect sources/sinks.
R. W. Balluffi

3.34 Theory of Dislocations (A)

Prereq.: —
G (1) **Not to be offered 1989-90**
3-0-9

Basic treatment of the structure and properties of dislocations in crystals. Particularly useful for students interested in applying dislocation concepts to the mechanical properties of materials. Extensive usage of elasticity theory. Includes dislocation topology; stresses and energies of straight and curved dislocations; interactions between dislocations; dislocation dynamics; effects of crystal structure on dislocations; interactions between dislocations and point defects; groups of dislocations.
R. W. Balluffi

3.36J Welding Engineering (A)

(Same subject as 13.17J)
Prereq.: 3.02
G (1)
3-0-6

See description under subject 13.17J.
K. Masubuchi

3.37 Welding and Joining Processes (A)

Prereq.: —
G (2)
3-0-3

Discusses a wide variety of processes and materials from the viewpoint of their fundamental physical and chemical properties. Specific topics: cold welding, adhesive bonding, diffusion bonding, soldering, brazing, flames, arcs, high-energy density heat sources, solidification, cracking resistance, shielding methods, and electric contacts. Emphasis on underlying science of a given process rather than a detailed description of the technique or equipment.
T. W. Eagar

3.38 Behavior of Metals at Elevated Temperatures (A)

Prereq.: 3.14
G (1)
3-0-6

Studies mechanical behavior of pure metals and alloys above the minimum recrystallization temperature. Mechanisms of deformation and fracture at elevated temperatures. Creep theories. Applications of stress rupture and thermal fatigue testing. Strengthening principles of superalloys and refractory metals.
N. J. Grant

3.39J Mechanical Behavior of Materials (A)

(Same subject as 22.74J)
Prereq.: 2.30, 3.11 or 22.71J
G (1)
3-0-9

Reviews elasticity theory. Elements of plasticity theory. Strengthening mechanisms in metals. Mechanical behavior of polymers. Application of principles of linear elastic fracture mechanics to brittle fracture and to fatigue crack propagation. Micromechanisms of fracture (cleavage, ductile fracture, fatigue, creep, stress corrosion cracking). Principles of failure analysis. Discusses case studies and reviews current research in fracture.
R. G. Ballinger, R. M. N. Pelloux

3.40J Physical Metallurgy (A) (Revised Content)

(Same subject as 22.71J)
Prereq.: 3.02, 3.11, or Permission of Instructor
G (1)
3-0-9

Discusses structure-property relationships in metallic alloys selected to illustrate some basic concepts of physical metallurgy and alloy design. Considers mostly mechanical properties. Also considers structural features: structural stability, grain size, interstitial and substitutional solutes, precipitates, second-phase particles, eutectics and eutectoids, and composites.
K. C. Russell

3.41J The Mechanics of Fracture

(Same subject as 2.34J)
Prereq.: 2.30
G (2)
3-0-9

See description under subject 2.34J.
R. M. N. Pelloux, D. M. Parks

3.43 Physics and Chemistry of Materials (A)

Prereq.: 8.03, 18.03
G (1)
4-0-8

Introduces physics and chemistry of materials, based on unified treatment of quantum physics, chemistry, and statistics of electrons, atoms, molecules, and solids. Includes review of classical mechanics and electromagnetic theory; basic concepts and formalism of quantum mechanics; free electron, molecular-orbital, and band theories; quantum statistics of electrons; defect and interface states; lattice heat capacities; Boltzmann theory of electrical and thermal transport; Ising model of order-disorder transformations; electronic phase transitions.
K. H. Johnson

3.44 Advanced Topics on the Physics and Chemistry of Materials (A)

Prereq.: 3.43
G (2)
4-0-8

Covers advanced topics on the physics and chemistry of materials not covered in the core subject 3.43. Includes molecular and crystal symmetry group theory; ligand field theory; computer applications of quantum chemistry to the electronic structures of materials; electronic structures of crystalline and noncrystalline materials, surface physics, chemisorption and catalysis; structural and electronic phase transitions, including superconductivity, lattice instabilities (martensitic transformation), and melting.
K. H. Johnson

3.45 Magnetic Materials (A)

Prereq.: 3.43
G (1)
3-0-9

Magnetization phenomena, origin of magnetism in a material, magnetic domains and domain walls, magnetic anisotropy, reversible and irreversible magnetization processes. Special topics: ferromagnetism of thin films and fine particles, magnetic recording, magnetic circuits, amorphous magnetic materials.
B. L. Averbach

3.46 Electronic Materials and Devices (A)

Prereq.: 3.20, 6.732J
G (1)
3-0-9

Evaluation of electronic and optical properties of materials from the standpoint of their crystal structure, energy bands, defects, and microstructure. Implications for junction design and properties including p-n, Schottky, MOS, and hetero-junctions. Discussion of materials aspects of new device structures such as quantum wells and high-electron mobility transistors.
N. Herbots

3.47 Electronic Materials Processing (A)

Prereq.: 3.20, 3.21
G (1)
3-0-9

Processing of electronic materials for device and circuit applications. Detailed discussion of techniques and theory for growth of device-quality crystals. Processes for integrated circuit fabrication including oxidation, junction formation, and metallization. Emphasis on relationships among processing, structure, and properties. Examples taken from materials processing for applications in VLSI, optoelectronics, and multi-layer integration.
C. V. Thompson

3.475 Compound Semiconductors (A)

Prereq.. 3.46, 3.47
G (2)
2-0-6

Properties and processing of materials systems used in semiconductor device technology. Emphasis on compound semiconducting systems (e.g., binary III-V and II-VI compounds) as well as more complex ternary and quaternary systems. A fundamental and practical approach to structure, imperfections, defect equilibrium, and processing. Implications for electrical, optical, and magnetic properties of homogeneous and heterogeneous structures.
L. C. Kimerling

3.48 Optoelectronic Materials (A)

Prereq.: 3.43 and 6.732J
G (2)
3-0-9

The fundamental mechanisms for magnetooptic and optoelectronic behavior in materials. Electronic structure, atomic arrangements, symmetry, effects on bandgap, drift mobilities, refractive index, trapping, charge depletion, Kerr and Faraday effects, emission phenomena, electroluminescence, photoemission, and laser phenomena. Materials design and processing for imaging and information storage.
B. L. Averbach

3.49 Special Problems in Electronic Materials (A)

Prereq.: —
G (1, 2, S)
Arr.

Advanced work in the field for qualified students. Course work involves lectures, conferences, assigned readings, or supervised laboratory work.
H. L. Tuller

3.50 Physical Chemistry of Metallurgical Processes (A)

Prereq.: 3.20
G (2)
3-0-6

Studies physicochemical nature of pyrometallurgical processes and systems. Nature and behavior of principal phases of interest: liquid metals, slags, fused salts, mattes, gas, and refractory materials. Nature of heterogeneous reactions among constituents of these phases. Application of physicochemical principles to analysis of behavior of pyrometallurgical processes.
J. F. Elliott

3.501 Physical Chemistry in Pyrometallurgical Processes (A)

Prereq.: 3.20
G (1) **Next offered 1989-90**
3-0-6

Studies current state of understanding of the thermodynamic and kinetic behavior of reactions, components, and phases in pyrometallurgical systems. Advanced treatment of the reactions among components in metals, gases, slags, and mattes. Emphasizes current literature on the subject.
J. F. Elliott

3.52 Materials Processing (A)

Prereq.: 3.02, 3.185, and 3.11 or 2.01, or equivalents
G (2)
3-0-6

Fundamentals of traditional and nontraditional materials processing. Coverage includes solidification, rapid solidification, sintering, deformation processing, and composite materials processing with strong emphasis on metallic materials. Particular attention paid to microstructural evolution during processing, and resulting material properties.
A. Mortensen

3.53 Electrochemical Processing of Materials (A)

Prereq.: 3.185
G (1)
3-0-6

Principles of electrochemistry: thermodynamics and kinetics of electrode processes, thermodynamic and transport properties of aqueous and nonaqueous electrolytes. Electrolytic processing: electrowinning, electrorefining, electroplating, electrosynthesis, electroslag remelting.
D. R. Sadoway

3.54 Corrosion — The Environmental Degradation of Materials (A)

Prereq.: 3.00
G (1)
3-0-6

Applies thermodynamics and kinetics of electrode reactions to aqueous corrosion of metals and alloys. Forms of corrosion and corrosion testing. Methods of corrosion control including alloy selection, water chemistry, design rules, anodic and cathodic protection, and coatings. Extension to environmental degradation of ceramics and polymers. Discusses materials degradation problems in marine environments, oil and gas production, energy conversion and generation systems.
R. M. Latanision

3.541 Oxidation and Corrosion of Materials at Elevated Temperatures (A)

Prereq.: 3.20, 3.21
G (1) **Next offered 1989-90**
3-0-6

Application of fundamental principles of thermodynamics and kinetics to determination of the mechanisms of the oxidation and corrosion of materials at elevated temperatures. Relationship of oxidation theory to design of alloys, and of coating materials for protection against oxidation. Discussions of high-temperature oxidation and corrosion problems that occur in systems for the conversion and utilization of energy, and in petrochemical and metallurgical industries.
G. J. Yurek

3.55 Macroscopic Transport in Materials Processing (A)

Prereq.: 18.03
G (2)
3-0-9

Elements of laminar and turbulent flow; heat transfer by conduction, convection, and radiation; mass transfer in laminar and in turbulent flow. Modeling of transport phenomena in industrial systems, including steelmaking, continuous casting, and vacuum degassing.
J. Szekely

3.552 Mathematical and Physical Modeling of Materials Processing Operations (A)

Prereq.: 3.55
G (2) **Next offered 1989-90**
2-0-7

Principles of mathematical and physical modeling of primary metals processing, welding, rapid solidification, and the processing of electronic materials. The transport equations as building blocks of mathematical models. Similarity criteria in building of physical models. Synthesis of an optimal modeling approach, involving mathematical models, physical models, and pilot plants.
J. Szekely

3.555 Materials Selection and Design (A) (Revised Unit)

Prereq.: 3.56
G (2) **Next offered 1989-90**
2-0-4

Synthesis of materials selection, design, and manufacturing from the viewpoint of the materials engineer. Includes relationships between material properties and performance, including design for strength, stiffness, failure mode, toughness, creep, fatigue, surface durability; databases of materials properties and their use; cost and performance criteria; interaction between selection and processing. Case studies used to illustrate integration of topics. Alternate years.
J. P. Clark

3.56 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. P. Clark, R. de Neufville

3.561 Materials Systems Analysis (A)

Prereq.: 3.56
G (2) **Not to be offered 1989-90**
2-0-4

Introduction to quantitative methods for analysis of technical and economic factors associated with the processing and use of materials. Includes techniques of microeconomic analysis, mathematical optimization, decision analysis, and simulation modeling. Application of these techniques to study production problems associated with metals, polymers, ceramics and composite materials, and competition among materials in selected applications. Alternate years.
J. P. Clark

3.565J Manufacturing/Technology Interface (A)

(Same subject as 13.685J, 15.365J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 15.365J.
J. M. Utterback

3.566 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
W. C. Flowers

3.576J Law, Technology, and Public Policy (A)

(Same subject as TPP 32J)
Prereq.: —
G (2)
3-0-6

See description under subject TPP 32J.
N. A. Ashford, C. Caldart

3.577 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

3.58 Seminar on Problems in Materials Policy and Economics

Prereq.: —
G (2)
2-0-4

Discussion of resource base and production capacity as determinants of materials supply, costs of production, nature of materials demand, materials markets, prices of materials, production cartels and price stabilization, materials substitution, conservation and recycling, and governmental policies concerning supply sufficiency. Materials of mineral and organic origin considered. Attention given to the relation of materials to the environment, energy consumption, innovation, and productivity. Open to qualified undergraduates.
M. B. Bever

3.595 Special Problems in Materials Engineering (A)

Prereq.: —
G (1, 2, S)
Arr.

Advanced work in the field for qualified students. Course work involves lectures, conferences, assigned readings, or supervised laboratory work.
J. P. Clark

3.60 Thermal and Tensor Properties of Ceramics (A)

Prereq.: 3.06 or 3.07
G (2) **Next offered 1989-90**
3-0-6

Analyzes tensor representation of properties of crystalline ceramics. Includes anisotropy, representation surfaces and effects of crystal symmetry, as well as application to piezoelectric and elastic properties and propagation of elastic waves in crystals. Discusses thermal properties: heat capacity, thermal expansion, and thermal conductivity, emphasizing materials and influences of microstructure.
B. J. Wuensch

3.601 Electrical, Optical, and Magnetic Properties of Ceramics (A)

Prereq.: 3.07
G (1) **Next offered 1989-90**
3-0-6

Analyzes electrical, optical, and magnetic properties of ceramics in terms of band theory, transport theory, and defect chemistry. Examines effects of materials processing, composition, and microstructure on properties. Discusses applications of theory towards new materials development.
H. L. Tuller

3.611 Polyphase Ceramics (A)

Prereq.: 3.06, 3.07
G (2) **Not to be offered 1989-90**
3-0-9

Applies phase transformation kinetics and multi-component phase equilibria to structure and properties of polyphase ceramics such as glass-ceramic compositions, triaxial porcelains, glazes, clay products, and refractories.
B. J. Wuensh

3.63 Ceramic Processes (A)

Prereq.: 3.06, 3.20
G (1)
3-0-6

Presents quantitative treatment of unit operations in powder processing-powder preparation, fabrication, and firing. Discusses glass processing-homogenization during melting; relationship to mixing theory-glass forming. Also covers growth of crystals, thermodynamics, transport processes, and kinetics in relation to structures developed.
H. K. Bowen

3.64 Special Problems in Ceramics (A)

Prereq.: —
G (1, 2, S)
Arr.

Explores advanced work in this field. Coursework includes lectures, conferences, assigned readings, and laboratory work.
B. J. Wuensch

3.691-3.699 Teaching Materials Science and Engineering

Prereq.: —
G (1, 2)
Arr.

Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. (Enrollment limited by availability of suitable teaching assignments.)
D. K. Roylance

3.70 Special Problems in Metallurgy (A)

Prereq.: —
G (1, 2, S)
Arr.

Minor investigation in one of the special branches of metallurgy. (Open only to students properly qualified in the special field.)
G. J. Yurek

3.711J Materials for Nuclear Applications (A)

(Same subject as 22.70J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 22.70J.
R. G. Ballinger

3.72J Nuclear Fuels (A)

(Same subject as 22.72J)
Prereq.: 3.13 or 3.14 or 22.71J
G (1) **Not to be offered 1989-90**
3-0-9

See description under subject 22.72J.
R. G. Ballinger

3.73J Radiation Effects in Crystalline Solids (A)

(Same subject as 22.73J)
Prereq.: 3.39J or 22.74J, 3.40J or 22.71J
G (2)
3-0-9

See description under subject 22.73J.
K. C. Russell

3.77 Laboratory Measurement and Control

Prereq.: —
G (1) **Not to be offered 1989-90**
2-1-3

Discusses laboratory techniques. Instrument characteristics. Basic electrical circuits. Transducers for force, stress, pressure, displacement, flow, and temperature input. Vacuum techniques. Special methods such as radio tracers, ultrasonic, laser. Control and recording systems. Analysis of experimental data.
J. T. Blucher

3.79 History and Anthropology of Materials Technology (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

See description under subject 3.17J.
L. W. Hobbs, H. N. Lechtman

3.82J Structural Mechanics in Nuclear Power Technology (A)

(Same subject as 1.56J, 2.084J, 13.14J, 16.261J, 22.314J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 22.314J.
O. Buyukozturk, M. S. Kazimi

3.90J Fracture of Structural Materials (A)

(Same subject as 1.591J, 13.16J)
Prereq.: 1.59J or 2.30 or 13.15J
G (1)
3-0-6

Analyzes criteria for crack initiation and propagation leading to structural failure. Studies fracture mechanics starting with Griffith theory for ideally brittle materials, through plane strain fracture toughness phenomena. Effects of geometry, rate, environment, fatigue, temperature, composition, and microstructure. Fracture behavior of welded metals, heat affected zone. Relation to dislocation mechanics. Significance of fracture surface morphology. Metals, polymers, fiber reinforced composites. Emphasizes current research in field.
K. Masubuchi, F. J. McGarry

3.91J Mechanical Behavior of Plastics (A)

(Same subject as 1.593J)
Prereq.: 3.064
G (1)
3-2-4

Relation among chemical composition, physical structure, and mechanical behavior of plastics or synthetic high polymers. Study of types of polymers; fundamentals of viscoelastic phenomena such as creep, stress relaxation, stress rupture, mechanical damping, impact; effects of chemical composition and structure on viscoelastic and strength properties; methods of mechanical property evaluation. Influences of plastics fabrication methods. Emphasis on recent research techniques and results. Individual laboratory projects investigating problems related to current research.
F. J. McGarry

3.92J Composite Materials (A)

(Same subject as 1.594J)
Prereq.: 3.064
G (2)
3-2-4

Concepts underlying formation, characteristics, and behavior of plastics-based composites such as fiberglass laminates, structural sandwiches, plywood, and load-bearing adhesive joints. Typical components such as metals, glass, synthetic and natural adhesives, plastics, foams, wood, paper, fabrics, and rubber. Correlation between adhesion principles and physical behavior. Methods of design, analysis, fabrication, and testing. Discusses failure mechanisms of chemical and mechanical types. Individual laboratory projects investigating problems related to current research.
J. F. Mandell, F. J. McGarry

3.93J Thermal Transitions, Optical and Electrical Behavior of Polymers (A)

(Same subject as 10.641J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Phase equilibria in polymer blends, crystallization and melting of polymers, vitrification, interaction of electromagnetic radiation with polymers, dielectric behavior, absorption of photons, and the fate of electronic excitation energy, electrical properties.
P. Cebe, R. E. Cohen, M. F. Rubner

3.930 Industrial Practice

Prereq.: —
U (S) [P/F]
0-6-0

Enrollment restricted to students in Course III-B. Provides academic credit for first approved work assignment at a company. For reporting requirements consult faculty industrial practice coordinator.
R. M. Pelloux

3.931 Industrial Practice

Prereq.: —
U (S)
0-6-0

Enrollment restricted to students in Course III-B. Provides academic credit for second approved work assignment at a company. For reporting requirements consult faculty industrial practice coordinator.
R. M. Pelloux

3.932 Industrial Practice (A)

Prereq.: —
G (1, 2, S)
0-6-0

Provides academic credit for graduate students in Course III-B for approved work assignments at companies. May be repeated.
R. M. Pelloux

3.94J Polymer Processing (A)

(Same subject as 2.820J)
Prereq.: 10.301
G (2)
3-0-9

See description under subject 2.820J.
T. G. Gutowski, D. K. Roylance

3.95J Physical Chemistry of Condensed Biological States (A)

(Same subject as 2.907J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 2.907J.
I. V. Yannas

3.951J Polymer Deformation and Fracture (A)

(Same subject as 2.921J)
Prereq.: 2.30 or 2.31, 2.32
G (1)
3-0-9

See description under subject 2.921J.
I. V. Yannas

3.97J Polymer Morphology and Properties Laboratory (A)

(Same subject as 10.66J)
Prereq.: Permission of Instructor
G (2)
1-5-6

See description under subject 10.66J.
R. E. Cohen, R. C. Armstrong, D. K. Roylance

3.99 Special Problems in Polymer Science and Engineering (A)

Prereq.: —
G (1, 2, S)
Arr.

Advanced work in the field. Lecture, conferences, assigned readings, and laboratory work.
M. F. Rubner

Course 4 Architecture

4.UR Undergraduate Research in Architecture

Prereq.: —
U (1, 2) [P/F]
Arr.

Research and project activities, which cover the range represented by the various research interests and projects in the Department.
Staff

4.01 Issues in Architecture

Prereq.: —
U (1)
3-3-6

Introductory architectural design studio about seeing and understanding the built world in a way that provides a framework of places for people. A series of cumulative exercises involving designing places for oneself, for a few people, for many people. Lectures, individual and group design projects. Intended for freshmen and sophomores.
S. Kanda, W. Hubbard

4.071J Design with Microclimate

(Same subject as 11.185J)
Prereq.: 8.01, 18.01
U (1) LAB
3-6-3

Introduces microclimate design principles through lecture and field investigations. Wind effects on buildings, noise control, solar and nocturnal radiation control, human comfort determination, thermal storage design. Investigates how vegetation affects microclimate and how microclimate influences vegetation. Modeling methods for testing design alternatives and measurement techniques for adequate site reconnaissance. Concludes with a comprehensive environmental design problem.
T. E. Johnson

4.09 Preparation for Ph.D. Thesis (A)

Prereq.: —
G (1, 2)
Arr.

Selects thesis subject, defines method of approach, and prepares preliminary thesis outline. Independent study, supplemented by frequent individual conferences with staff members. Restricted to doctoral candidates.
S. Anderson

4.125, 4.126 Architectural Design[1]

Prereq.: 4.26
U (1, 2)
0-12-9

Establishes basic attitudes to architectural organization and its reflection in form. Includes projects where imposed conditions of site, program, and building system emphasize the interrelationship of fundamental elements in the pattern of decision making that constitutes architectural design. Develops presentations through drawings and models. Intended for juniors, seniors, and entering graduate students.
Architectural Design Staff

4.131, 4.132 Architectural Design[1]

Prereq.: 4.125, 4.126
U (1, 2)
0-12-9

4.143, 4.144 Architectural Design (A)[1]

Prereq.: 4.125, 4.126
G (1, 2)
0-12-9

Projects develop awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available for effective satisfaction of common environmental needs. Design for intensive, extensive, and multiple space uses. Buildings of multistory construction. Considers natural and artificial environmental controls as they influence the design concepts and the installations associated with them.
Architectural Design Staff

4.155, 4.156 Architectural Design (A)[1]

Prereq.: 4.144
G (1, 2)
0-12-9

Emphasizes setting of architectural work as part of an organized community in projects having to do with built-up areas, as well as those on new sites. Studies plans for long-range development, giving students increasing experience in the analysis of real-life situations requiring program research.
Architectural Design Staff

[1] Note about the subjects in Architectural Design: The sequence in Architectural Design is a cumulative program. Its successful completion by the student is subject to evaluation by the staff independent of formal grades accumulated.

4.160 Urban Settlement Design in Developing Countries I (A) (Revised Unit)

Prereq.: Permission of Instructor
G (2)
0-9-6

4.161 Urban Settlement Design in Developing Countries II (A) (Revised Unit)

Prereq.: 4.160
G (1)
0-9-6

Advanced projects on urban settlement issues for low-income groups in developing countries. Aims: to prepare designers to participate effectively in the process of shaping the environment; to develop tools to define and evaluate design determinants; and to make these tools available to those concerned and responsible for action at the policy-making level.
R. Goethert

4.163J Urban Design (A)

(Same subject as 11.332J)
Prereq.: Permission of Instructor
G (2)
Arr.

The design of urban environments. Strategies for change in large areas of cities, to be developed over time, involving different actors. Fitting forms into natural, man-made, historical, and cultural outlooks; enabling desirable activity patterns; conceptualizing built form; providing infrastructure and service systems; guiding the sensory character of development. Involves architecture and planning students in joint work; requires individual designs or design and planning guidelines.
D. Frenchman

4.164 Housing Design and Methods (A)

Prereq.: 4.211, *4.224*
G (2)
0-12-9

Understanding problems related to design of residential environments and development of skills to deal with these problems. Emphasizes application of methods that deal with issues of change, evaluation of the capacity of a given environment to accommodate to changing uses and lifestyles. Assesses the impact of changing normative criteria on the physical environment. Developing alternative solutions within a given set of constraints. Projects in the design of buildings and of urban (residential) environments.
N. Hamdi

4.165 Architectural Design for Islamic Cultures (A)

Prereq.: 4.231
G (2)
0-12-9

Architectural design studio focusing on a specific urban area in a Muslim country. Projects selected to develop awareness of the principal issues facing the architectural designers in those countries. Cross-cultural comparisons used as part of the teaching method. Consideration of environmental, social, and aesthetic factors.
R. Lewcock, A. Badshah

4.181-4.185 Architectural Design Workshops (A)

Prereq.: 4.131 or 4.143
G (1, 2)
Arr.

Form-making exercises that explore and/or inquire into a generic architectural design problem. The problem may be prototypical or a particular aspect of a whole project; it is often research-oriented and non-site specific.
Architectural Design Staff

4.191, 4.192 Special Problems in Architectural Design

Prereq.: —
U (1, 2)
Arr.

4.195, 4.196 Special Problems in Architectural Design (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Architectural Design Staff

4.203 Computers and Architecture I

Prereq.: 4.01
U (1, 2)
3-6-3

Provides a general and up-to-date survey of the contribution of computers and associated imaging technologies in architectural education, practice, and research, utilizing a high-level programming language. Presentations include case studies of computer application in architectural practice, and current research in computer graphics, color modeling, computational video, and man-machine interaction. Emphasis on digital modeling. Previous programming experience useful but not required. Limited enrollment.
F. Miller

4.204 Computers and Architecture II (A)

Prereq.: 4.203
G (2)
3-0-6

Project-oriented subject in which topics introduced in 4.203 are further developed, particularly in the areas of micro-CAD, visual information systems, and knowledge base engineering. Work relates to ongoing research in the Computer Resource Laboratory.
F. Miller

4.206 Form Processing Workshop (A)

Prereq.: 4.143, 4.204
G (2)
4-0-8

Explores architectural form-making in a hybrid media setting, incorporating tools and processes of both traditional paper-based and emerging computer-based media. Themes include manipulation of formal references, projective design exercises, and explorations into the role of various media in representation and description. Limited enrollment.
F. Miller

4.211 Interventions to Urban Housing (A)

Prereq.: 4.125 or 4.126
G (1)
3-3-6

Introduces the relative roles that users and institutions play in shaping the urban residential environment and the processes of planning and building. Evaluating the evolution of these processes in various cultural and historical contexts, tackling related design information and regulatory controls. Assessing professional, governmental, and industrial interventions in these processes, types, tools, and implications. Case studies illustrate alternative approaches at dwelling and neighborhood levels.
N. Hamdi

4.224 Thematic Design: Theory (A)

Prereq.: 4.125, 4.126
G (2)
3-4-5

Lectures and exercises on the principles of thematic design. Theme, pattern, and type as ordering devices. Spatial and physical thematic systems. Levels among thematic systems. Change and the dimension of time in design. Territory and territorial order. Inside-outside and public-private transitions. Social and personal values and their relations to form. Provides understanding and skills for general use in architectural and urban design.
N. J. Habraken

4.225 Thematic Design: Methods (A)

Prereq.: 4.125, 4.126
G (1)
3-4-5

Methodological principles of thematic design and their application. Develops a spatial theme and its elaboration on the level of the building as well as the urban tissue. Involves development of variants within given thematic rules; evaluation of the capacity of specific configurations; analysis of zones, sectors, and sector groups; formulation and use of selection and position rules. Familiarizes students with generation and control of more complex form systems and appropriate use of available methods.
N. J. Habraken

4.227 Issues of Theory and Method in Design (A)

Prereq.: Permission of Instructor
G (1)
2-0-4

Examines questions of methodology in design, theory of design, and theory of the built environment based on readings and visual documentations. Topics vary each semester.
N. J. Habraken

4.231 Introduction to Design for Islamic Cultures

Prereq.: Permission of Instructor
G (1)
3-6-3

Introductory workshop concerned with the understanding of built form in Muslim countries, both at the individual building and the urban scale. Design methods and design and its applications addressed in the three major sections of the workshop: describing and analyzing the urban and rural environment, methods of design, and form vocabularies. Major themes explored through lectures and case studies.
R. Lewcock, A. Badshah

4.243 Small Built-Collage (A)

Prereq.: 4.143
G (1)
3-0-9

The intrinsic attributes/generative principles of built- and landscape-form/additive directional-field organization. A progression of intensifications includes surfaced relief, "habitable" planar assemblages, and territorial screens.
M. K. Smith

4.248, 4.249 Special Projects in Visual Design for Architects (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplemental work on individual or group basis on visual design relevant to architecture. Registration subject to prior arrangement of subject matter and supervision by staff.
Staff

4.251 Introduction to Computational Design Tools (New)

Prereq.: —
U (1)
3-6-3

Provides an introduction to computational tools available to designers for observation and documentation of precedents, for design projection, and for analysis and simulation of designs. Emphasis is on developing expressive ability with state-of-the-art tools, and on structural parallels between theories of design and computational models. Lectures, case studies, and laboratory projects.
J. Anderson

4.255 Computational Design Workshop (A) (New)

Prereq.: 4.251, 4.126
G (1, 2)
3-6-3

Form-modeling exercises which explore uses of computational tools to represent, analyze, and generate designs. Includes individual and group projects which apply graphics editors, visual documentation tools, and thematic description languages. Limited enrollment.
J. Anderson

4.256 Computational Design Models (A) (New)

Prereq.: 4.251
G (2)
3-0-6

Introduction to construction of intelligent design systems. Case studies from related applications of AI principles in other design fields. Projects develop programs which express, exercise, and exhibit knowledge about particular architectural and environmental design issues. Discussion of expected developments in computational design tools.
J. Anderson

4.26 Observing Form in Context

Prereq.: 4.01
U (2)
3-3-6

Introduction to disciplined observation of the built environment. Study of architectural places and gestures in their context by observing qualities of space, light, form, and materials. Lectures, field studies, drawings, sketches, designs, and discussions.
B. Zevin

4.261 Design Skills Workshop

Prereq.: Permission of Instructor
G (1)
Arr.

Supplements Level I Architectural Design Studio. Emphasizes acquisition of drawing and observational skills. Field trips, guest lectures, and presentations focus on issues specific to developing a design drawing repertoire. Individual tutorials in graphic skills. Restricted to and intended for entering M.Arch. students.
W. L. Porter

4.263 Seminar in Architecture

Prereq.: —
G (1)
0-3-0

Introduction to the professional architecture program, dealing both with bringing incoming students into the intellectual context of the Department and addressing selected topics in architecture and architectural education in general. Recommended for all incoming M.Arch. students.
W. L. Porter

4.273 Methods of Inquiry in Architecture Studies

Prereq.: Permission of Instructor
G (1)
3-2-7

Introduces ways of acquiring systematic knowledge about the built environment. Examines what constitutes valid knowledge in architecture and compares various approaches to the understanding of the built environment. Emphasizes theory building and testing appropriate to architectural studies. Requirements include exercises aimed at improving skills in conceptualizing problems, developing concepts, interpreting information, and communicating results. Required of all first-year S.M.Arch.S. students.
J. Beinart

4.278J Design Research Seminar (A)

(Same subject as 11.338J)
Prereq.: —
G (1, 2)
2-0-7

See description under subject 11.338J.
D. A. Schon

4.281 Preparation for M.Arch. Thesis (A)

4.282 Preparation for S.M.Arch.S. Thesis (A)

4.283 Preparation for S.M.Vis.S. Thesis (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
Staff

4.291 Special Topics in Design Information

Prereq.: Permission of Instructor
U (1, 2)
Arr.

4.295-4.299 Special Topics in Design Information (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Staff

4.30 Basic Structural Theory

Prereq.: 8.02, 18.02
U (2) SD
3-3-6

Introduces the static behavior of structures and strength of materials. Reactions, truss analysis, stability of structures. Stress and strain at a point, shear and bending moment diagrams. Stresses in beams, Mohr's Circle, column buckling. Deflection of beams. Laboratory to solve structural problems by building simple models and testing them.
L. B. Groisser

4.315J Structural Engineering Laboratory

(Same subject as 1.105J)
Prereq.: —
U (1) LAB
0-3-3

See description under subject 1.105J.
G. B. Baecher

4.331 Synthesis of the Behavior of Structural Systems I

Prereq.: —
G (1)
4-0-5

4.332 Synthesis of the Behavior of Structural Systems II

Prereq.: 4.331
G (2)
4-0-5

Classification of the most characteristic patterns of the behavior of basic structural materials, structural systems, and their components. Catenary, arch, and shell structures. Flow of internal forces in deep walls and beams; trusses; frames and plates. Studies relationship between shape of structure and its technological and mechanical efficiency as a way to general optimization. Applies mastery of simplified procedures — graphical and numerical — to the design of structural systems.
W. P. Zalewski

4.341 Framing Systems for Small Structures

Prereq.: 4.30 or 4.331
G (1)
4-0-5

Approximate methods for the initial selection of framing systems for vertical loading. Loading conditions and building codes. Design of beams for shear, bending moment, and deflection criteria; design of columns. Application to a wood house, including alternative wood floor framing, walls, columns, and rafters. Optimum truss depth.
L. B. Groisser

4.348 Structural Design Workshop (A)

Prereq.: 4.126, 4.30 or 4.331, 4.402J
G (2)
4-4-4

Allows participation in faculty-initiated structural design research projects related to architectural applications of new building components and methods of their assembly.
W. P. Zalewski

4.38, 4.39 Special Problems in Structural Design (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary structural design on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
W. P. Zalewski

4.401 What is a Building? (New)

Prereq.: —
U (1)
3-0-6

Building is one of the most ancient and most universal human activities. From the cave to the teepee, to the modern skyscraper and the Super Bowl, human ingenuity and skill have transformed raw materials into structures, structures into shelter, and shelter into architecture. The story of the evolution of building construction from craft to industry rendered in lectures, by case studies, demonstrations, and field trips. Intended for freshmen and sophomores.
E. Dluhosch

4.402J Building Construction I

(Same subject as 1.411J)
Prereq.: —
U (2)
3-4-5

Basic principles of materials and methods of construction as applied to common generic building types. Integration and detailing of load supporting, structural elements and systems, with nonload supporting elements of the overall building fabric. Workshop includes development of a basic set of construction documents, computer-aided tutorials, field trips, and demonstrations.
E. Dluhosch

4.403J Building Construction II

(Same subject as 1.412J)
Prereq.: 1.02, 1.04; or 4.402J, 4.30 or 4.331
U (1)
2-4-3

Integrated analysis and on-site case studies of selected building projects and/or their constituent subsystems and elements. Investigates operational integration and technical implementation of materials and processes to realize explicitly stated performance criteria by means of the best current building practice.
Staff

4.408, 4.409 Special Problems in Building Construction (A)

Prereq.: 4.30, 4.402J
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
E. Dluhosch

4.41 Building Technology Laboratory (New)

Prereq.: 8.02, 18.02
U (1) LAB
0-4-2

Basic concepts of building technology and experimental methods explored in a realistic laboratory setting. One or two experimental projects dealing with one facet of building technology such as lighting, moisture control, energy, or structures. Computers used for data acquisition or simulation of system performance.
L. Glicksman

4.415 Environmental Technology (A)

Prereq.: 4.30 or 4.331, 4.402J, 4.45
G (2)
3-0-6

Cross-disciplinary subject building on basic technical information in structures, energy, and building construction while integrating areas such as fire protection and building security. Office and site visits, outside lecturers, and team teaching to provide a technical and practical base for architectural design practice.
Staff

4.42J Fundamentals of Energy in Buildings (New)

(Same subject as 1.42J, 2.45J)
Prereq.: 8.02, 18.02
U (1)
3-0-9

Introduction to energy fundamentals important to buildings. Conservation of energy. Properties of pure substances, gas mixtures, psychrometrics. Heat pumps and refrigeration cycles, limiting thermodynamic performance. Heat transfer within buildings and major components.
L. Glicksman

4.43 Architectural Acoustics

Prereq.: 4.402J
U (1)
4-0-5

Describes desirable and undesirable interactions between people and sound, indoors and outdoors, and uses this information to develop acoustical design criteria for architecture and planning. Physical principles of sound generation, propagation, and reception. Techniques and data used to provide good hearing conditions in interior and exterior spaces, and to control noise in rooms, buildings, sites, and regions. Practical examples and case-history illustrations.
C. J. Rosenberg

4.45 Uses of Energy in Buildings

Prereq.: 4.402J
U (1)
3-0-6

Explores energy utilization in buildings, specially emphasizing energy conservation. Emphasizes a qualitative understanding of the various energy flows affecting buildings, as well as a quantitative understanding of the major factors influencing building design and operation. Topics: thermal comfort, climatic analysis, thermophysical properties of building materials, psychrometrics, heat gain and loss, lighting, and HVAC selection and integration.
Staff

4.46 Solar Architecture (A)

Prereq.: 4.45
G (2)
3-0-6

Develops and applies principles for the utilization of solar energy in buildings. Covers methods for designing solar energy systems and predicting their performance. Topics: solar movement; solar radiation; fundamentals of solar heating and cooling; active solar design for space heating, cooling, and domestic hot water; passive solar design for space heating and cooling; performance and economic analysis; and the integration of solar concepts into building design.
T. E. Johnson

4.468 Energy Conscious Design (A)

Prereq.: 4.071J, 4.131 or 4.143, 4.45, *4.46*
G (2)
4-5-12

Examines energy-conscious design issues using a commercial design problem in a studio format. Presents design and modeling methods for predicting thermal and lighting behavior. Studies building material choices and introduces the latest building technology for conserving energy.
T. E. Johnson

4.474 Uses of Daylighting in Buildings (A)

Prereq.: 4.45
G (1)
3-0-6

Explores and analyzes in detail the principles associated with utilization of daylighting in buildings. Topics: history of daylighting, fundamentals of light, daylight availability, strategies for daylighting design, architectural considerations, calculations and design methods, thermal and energy considerations, integration of daylighting with artificial lighting, lighting control strategies and integration of daylighting into building design.
G. Clark

4.48 Integration of Mechanical Systems (A)

Prereq.: 4.45
G (2)
3-0-6

Major issues in bringing a building and its mechanical systems into a well-integrated whole. Mechanical systems' interaction with the building envelope and the structure. HVAC topics including comfort conditions, building and occupancy types; HVAC system types including control, unitary, heat pump; building automation and control by microcomputer.
W. Wright

4.497-4.499 Special Problems in Environmental Controls (A)

Prereq.: —
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Staff

4.51 Building Systems (Revised Content)

Prereq.: Permission of Instructor
G (1)
3-0-6

Explore the relationship between structure, the processes of construction, and form. The influence of functional and contextual constraints on choice of materials and elements, which make up the building fabric. Study major precedents in the evolution of architectural types, as related to materials and methods of construction, with special emphasis on new materials, such as reinforced concrete and steel and the use of mechanized and industrialized processes in building construction.
E. Dluhosch

4.52 Building Systems Workshop (A) (Revised Content and Unit)

Prereq.: 4.51
G (2)
3-6-3

Use of contemporary and innovative materials and methods of construction in terms of their coordination, compatibility, and jointing with each other, to be applied to specific generic building types or pre-coordinated subsystems. Choice of technological alternatives and their relationship with the conceptual assumptions of various so called "systematic" approaches to design, and their effect on built form.
E. Dluhosch

4.54 Introduction to Building Economics (Revised Content)

Prereq.: 14.01 or 14.014J or 15.001
U (2)
4-2-6

Reviews basic analytical concepts of micro- and macroeconomics, with applications to building and industry. Provides an economic overview of the entire building process, with an emphasis on building technology issues. Prepares for microeconomic analysis of planning, real estate development and management, design, construction, and operation and maintenance of buildings, as well as for inter-industry analysis of the building industry in developed and developing countries. Requires participation in study groups using computer tools.
R. Bon

4.55 Building Economics (A) (Revised Content and Unit)

Prereq.: Permission of Instructor
G (1)
4-4-4

Presents the subject in four independent three-week modules: review of micro- and macroeconomic concepts relevant to the building field, project evaluation tools and techniques for building decisions, real property management tools and techniques, and inter-industry analysis of the building industry. Requires participation in development of decision-support systems for project evaluation and real property management, as well as empirical research projects into building industry structure using computer tools and databases.
R. Bon

4.58 Space Habitat Design Workshop (Revised Content)

Prereq.: —
G (1)
Arr.

Explores the limits of building technology that will be available by the end of the century in a multidisciplinary and interdepartmental framework. Focuses on design and construction of space stations, bases, and colonies, with an emphasis on habitation issues. Also studies social, political, legal, and economic aspects of space architecture. Emphasizes long-term possibilities for peaceful colonization of space. Requires participation in design teams developing overall space habitat configurations and construction strategies.
R. Bon

4.59 Special Topics in Building Economics (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary study on selected topics such as managerial, economic, socioeconomic, and/or political problems connected with the building industry. Registration subject to prior arrangement for subject matter and supervision.
R. Bon

4.601 Topical Studies in the History and Theory of Art

Prereq.: —
U (1) HASS-D/HUM-D
4-0-5

Introduces selected topics in the history and theory of painting and sculpture from prehistoric times to 1800, often focusing on a central theme. Examines key objects in terms of style, iconography, and function, and considers them as expressions of the social, political, religious, and intellectual values of their respective cultures. Emphasizes discussion of the different functions of art and basic modes of artistic formation.
A. Wagner

4.605 Introduction to the History and Theory of Architecture

Prereq.: —
U (2) HASS-D/HUM-D
4-0-5

Provides an outline of the history of architecture and urbanism from Ancient Egypt to the present. Analyzes buildings as the products of culture and in relation to the special problems of architectural design.
F. Passanti

4.625 Selected Topics in Architecture in the Middle Ages

Prereq.: 4.605
G (1)
3-0-6

A history of buildings from the time of Rome's conversion to Christianity to the beginning of the Renaissance. Deals with the history of architectural form, methods of design and construction, and the historical and physical contexts of the buildings. Open to qualified undergraduates.
D. H. Friedman

4.628 Advanced Study in Medieval Architecture (A)

Prereq.: Permission of Instructor
G (1 or 2)
Arr.

Seminar on a selected topic from medieval architecture. Requires original research and presentation of oral and written reports.
D. H. Friedman

4.633 French Architecture and Urbanism (New)

Prereq.: 4.605
G (1)
3-0-6

A history of architectural and urban forms in France from the reign of Francis I through that of Louis XV. The formation of the French classical style considered in relation to the political, economic, and cultural changes which made France the leading power in Europe during the time of Louis XIV.
M. Benes

4.635 Renaissance Architecture

Prereq.: 4.605
U (1) HASS
3-0-6

A history of the architecture of the 15th and 16th centuries in Italy. The formation and development of the classical style, drawing and model making, the relationship between architecture and the fine arts, buildings and their patrons, architectural theory, architecture and politics.
D. H. Friedman

4.636 Baroque and Rococo Architecture

Prereq.: 4.605
U (2) HASS
3-0-6

A history of European architecture in the 17th and 18th centuries. Works of Bernini, Borromini, Mansart, Wren, Juvarra, and Neumann. The major developments in the history of architectural design in the context of the political and cultural environment of the period.
D. H. Friedman

4.637 Renaissance and Baroque Gardens in Europe

Prereq.: 4.605
G (1)
3-0-6

Gardens from the 15th to 18th centuries, with particular emphasis on Italy and France. Gardens studied for their qualities as architecture, art, and analogues to urban and territorial experiences by relating them to the key contexts in each country.
M. Benes

4.638 Advanced Study in Renaissance Architecture (A)

Prereq.: Permission of Instructor
G (1 or 2)
Arr.

Seminar on a selected topic from Renaissance architecture. Requires original research and presentation of oral and written reports.
D. H. Friedman

4.639 Advanced Study in 16th-, 17th-, and 18th-Century Architecture (A)

Prereq.: Permission of Instructor
G (1)
Arr.

Seminar on a selected topic from architecture of the period. Requires original research and presentation of oral and written reports.
H. A. Millon

4.642 19th-Century Art

Prereq.: —
U (2) HUM-D
4-0-5

Survey of major artists and movements in 19th-century European painting and sculpture. Emphasis on emerging phenomena and concepts characteristic of the century. For example: the avant-garde, "art for art's sake," the museum and exhibition, the dealer/critic system, and the engagement of art and politics.
A. Wagner

4.645 Selected Topics in Architecture — 1750 to the Present

Prereq.: 4.605
G (1)
3-0-6

General study of modern architecture in Europe and America in the context of architectural and social programs. Open to qualified undergraduates.
S. Anderson

4.646 American Landscapes, Towns, and Buildings

Prereq.: 4.605
G (1)
3-0-6

Introduces environmental history in the US, concentrating on 19th- and 20th-century developments. Open to qualified undergraduates.
S. Anderson, D. H. Friedman

4.647 American Architecture: Boston

Prereq.: 4.605
G (2)
3-0-6

Studies urban and architectural development of Boston and its region. Selected topics in American architecture and urbanism as context for or comparison with Boston. Open to qualified undergraduates.
S. Anderson, D. H. Friedman

4.648 The City of Rome: Architecture, Urbanism, Suburban Territory (A) (New)

Prereq.: Permission of Instructor
G (1)
3-0-6

Seminar on Rome and its surrounding territory from the Renaissance to the 19th century. Urban, architectural, and landscape forms studied as the result of intersections between the ambitions of the popes and the patriciate classes, the projects of architects, and the layers of urban fabric since Antiquity. Topics vary.
M. Benes

4.651 20th-Century Art

Prereq.: —
U (1) HUM-D
4-0-5

Cubism, Futurism, Constructivism, and other phases of early 20th-century art, during which the theories, styles, and attitudes of contemporary art were formulated. Dadaism, Surrealism, and other intermediate phases leading to Abstract Expressionism in New York. Considers Post-Painterly Abstraction styles, Pop Art, Minimalism, and the resurgence of Realism both historically and critically.
A. Wagner

4.653 Advanced Study in 20th-Century Art (A)

Prereq.: Permission of Instructor
G (2)
Arr.

Seminar on a selected topic from 20th-century art. Requires original research and presentation of oral and written reports.
A. Wagner

4.655 Modern Architecture in Europe from 1895 to the Bauhaus (A)

Prereq.: 4.645
G (2)
3-0-6

Art and architecture in Europe from the late 19th century to the time of the Nazi repression of modern art. Intensive study of the people, works, and controversies from which the European "modern movement" emerged, leading in turn to the transformation of American architecture.
S. Anderson

4.656 Advanced Study in Twentieth-Century Architecture (A) (Revised Content)

Prereq.: Permission of Instructor
G (2)
3-0-6

Seminar on a selected topic in twentieth-century architecture. Focus on the formation of European modernism and its later reception in Europe and elsewhere. Requires original research and presentation of oral and written reports.
F. Passanti

4.657 Advanced Study on Le Corbusier (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Seminar on Corbusier. Requires original research and presentation of oral and written reports.
F. Passanti

4.658 Advanced Study in Modern Architecture (A)

Prereq.: Permission of Instructor
G (1 or 2)
Arr.

Seminar on a selected topic in the architecture of the late 18th century to the present. Requires original research and presentation of oral and written reports.
S. Anderson

4.661 Theory and Method in the Study of Architecture and Art (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Studies theoretical and historiographical works pertaining to the fields of architecture, art, and environmental studies. Members of seminar pursue work designed to elucidate and criticize their own presuppositions and methods. Open only to Ph.D. candidates and other advanced students. May be repeated for credit.
S. Anderson

4.663 Studies Toward a Theory of Architecture and Environmental Design (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Considers contemporary theoretical positions. Requires reports in the context, criticism, or support of the seminar thesis.
S. Anderson

4.664 Criticism of Architecture (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Surveys various approaches (social, environmental, economic, compositional, structural, functional) and bases for the criticism of architecture. Emphasizes the formal bases of criticism. History of criticism, relation of criticism and history, value of criticism to the profession, criticism as a means of achieving quality in architecture, and criticism as a rational and emotional response to architecture.
S. Anderson

4.665 Contemporary Architecture: A Critical Review (A) (New)

Prereq.: 4.645
G (2)
3-0-6

Critical review of works, theories, and polemics of the last 25 years. Aim is a historical understanding of the period and the development of a meaningful framework to assess the present situation in architecture. Intended for advanced M.Arch. students.
F. Passanti

4.671 History of Urban Form (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Studies in the history of the physical city from Antiquity to the present, with points of special focus determined by the instructor. Analyzes the typologies of urban buildings, public places, and city plans in their relation to changing contexts of culture, politics, and the structure of public and private institutions.
D. H. Friedman

4.673 Seminar in Urban Communal Space (A)

Prereq.: Permission of Instructor
G (2)
Arr.

A working seminar conducting continuing research on the sociophysical structure of urban communal space. Attention to the literal qualities of this space and especially to the models by which the form, meaning, and use of communal space are understood and changed. Students will produce theoretical or critical essays, graphic analyses, formalizations or designs. Limited enrollment.
S. Anderson

4.676 Advanced Study in Landscape Architecture (A) (New)

Prereq.: Permission of Instructor
G (2)
3-0-6

Seminar on selected topics in designed landscapes and gardens. A broad range of methodological approaches used to define the key contexts of landscapes historically and in contemporary design. Topics include theory, cartography, landscape painting, agrarian history, and large territorial structures such as road systems and forests.
M. Benes

4.678 Advanced Study in the History of Cities (A)

Prereq.: Permission of Instructor
G (1 or 2)
Arr.

Seminar on a selected topic on cities and urbanism. Requires original research and presentation of oral and written reports.
S. Anderson

4.684 Islamic Architecture to 1500

Prereq.: —
U (1) HASS
3-0-6

Views Islamic architecture within the continuum of ancient Near Eastern architecture. Examines the regional synthetic styles that combine Greco-Roman and local architectural traditions in order to explain the sources and archetypes of Islamic architecture in Umayyad and Abbasid times. Discusses "classical" Islamic architecture in the Near East and North Africa (from 1000 to 1500), emphasizing its common forms and themes and pointing out its regional diversity.
Y. Tabbaa

4.685 Islamic Architecture 1500 to Present

Prereq.: —
U (1) HASS
3-0-6

The division of Islamic architecture into three quite diverse traditions — the Ottomans in Turkey and the Arab world, the Safavids in Iran, and the Mughals in the Indian subcontinent — examined within the context of premodern state formation. The decline of these traditions and the concomitant rise of eclectic, historicist, Europeanizing and, ultimately, colonial styles. The modernist interlude and the ongoing search for an "appropriate" style reviewed, particularly in Turkey, India, and the Arab world.
Y. Tabbaa

4.686 Form and Meaning in Medieval Islamic Architecture (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Discusses methods of finding meaning in Islamic architecture, using the medieval Middle East as its field of inquiry. Emphasizes the use of iconography, philology, theology, and philosophy to investigate the meaning of forms and the expressive content of architectural styles. Requires original research and presentation of oral and written reports.
Y. Tabbaa

4.687-4.689 Special Studies in the History, Theory, and Criticism of Architecture and Urban Form in the Islamic World (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Special topics in the history, theory, and criticism of architecture and urban form in the Islamic World, varying at the discretion of the instructor.
Y. Tabbaa

4.691 Special Studies in the History, Theory, and Criticism of Art

Prereq.: —
U (1, 2)
Arr.

4.692, 4.693 Special Studies in the History, Theory, and Criticism of Art (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Individual or group projects on topics in the history, theory, and criticism of art. Registration subject to prior arrangement for subject matter and supervision by staff.
A. Wagner

4.695 Special Studies in the History, Theory, and Criticism of Architecture and Urban Form

Prereq.: —
U (1, 2)
Arr.

Individual or group projects in the history, theory, and criticism of architecture and urban form. Registration subject to prior arrangement for subject matter and supervision by staff.
S. Anderson

4.696-4.699 Special Studies in the History, Theory, and Criticism of Architecture and Urban Form (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Special topics in the history, theory, and criticism of architecture and urban form, varying at the discretion of the instructor.
S. Anderson

4.713 Architectural Theory and Function in Islamic Societies (A)

Prereq.: Permission of Instructor
G (1)
3-6-3

Analyzes theoretical approaches to creative activity in Islam, comparing and contrasting it with observable practice at different times and places in the Muslim world. Discusses the functioning of many elements of design in the architecture and urbanism of Islamic societies, and probes the real significance of the theories, practices, and functions to the individual, society, and to the designer, in light of the changes taking place in the Islamic world.
R. Lewcock

4.714 Built Form and Society (A)

Prereq.: Permission of Instructor
G (2)
3-6-3

Analyzes the relationship of built form to determinism in Muslim and other cultures, i.e., the theories that physical factors, defense, scarcity of arable land, etc., may determine the built form. Discusses other theories that social and religious values and beliefs may sometimes have a deterministic effect in establishing architectural and urban form, attempts to construct a rational method and analysis using evidence from many areas, and concludes by examining consequences for the design of built form.
R. Lewcock

4.715J Politics, Technology, and Development in the Middle East (A)

(Same subject as 17.558J, 1.255J, 11.488J, 21.485J, STS 509J)
Prereq.: —
G (1)
3-0-9

See description under subject 17.558J.
R. Lewcock, N. Choucri, F. Moavenzadeh, K. Keniston

4.716J Technology, Business, and Public Policy in the Middle East (A)

(Same subject as 17.560J, 11.489J, 1.256J)
Prereq.: —
G (2)
3-0-9

See description under subject 17.560J.
W. L. Porter, N. Choucri, F. Moavenzadeh, L. Trilling

4.721J Introduction to the Development Industry

(Same subject as 11.430J)
Prereq.: —
G (1)
2-0-7

See description under subject 11.430J.
J. McKellar

4.724 Design for Development (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Introduction to the design process from the perspective of the developer. Includes the developer/architect relationship; quality and design; interrelationship of form, function, and financial outcome.
M. Buckley, D. Frenchman

4.726J Site Planning

(Same subject as 11.336J)
Prereq.: Permission of Instructor
G (1)
4-4-4

See description under subject 11.336J.
J. McKellar

4.736J Introduction to Urban Design and Development

(Same subject as 11.301J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 11.301J.
D. Frenchman

4.743J Housing and Neighborhood Planning (A)

(Same subject as 11.420J)
Prereq.: 11.200 or 4.144
G (2)
4-0-8

See description under subject 11.420J.
P. Clay

4.746J Environmental Design Policy and Action (A)

(Same subject as 11.337J)
Prereq.: —
G (1)
3-0-6

See description under subject 11.337J.
J. de Monchaux, J. M. D. Schuster

4.747J Theory of City Form (A)

(Same subject as 11.330J)
Prereq.: 11.001 or 4.736J or 11.301J
G (2)
Arr.

Theories about the form that settlements should take. Attempts a distinction between descriptive and normative theory by examining examples of various theories of city form over time. Concentrates on the origins of the modern city and theories about its emerging form, including the transformation of the 19th-century city and its organization. Analyzes current issues of city form in relation to citymaking, social structure, and physical design.
J. Beinart

4.748J Cities of Tomorrow (A)

(Same subject as 11.335J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 11.335J.
D. Frenchman

4.749 Advanced Seminar in City Form (A)

Prereq.: 4.747J, 11.330J
G (1)
Arr.

Examines in greater depth themes from the basic subject in city form theory. Introduces new concepts from current research and practice for analysis by the seminar participants. Requirements include presentation to the seminar of a theoretical project undertaken by each student.
J. Beinart

4.751 Urbanization and Design in Developing Countries (A) (Revised Content)

Prereq.: Permission of Instructor
G (1)
3-3-6

Identifies and examines shifts in issues and approaches facing designers, from mass housing to core housing to site and services. Focus on housing design, land planning, and service provision. Extensive case studies from Africa, Latin America, and Asia.
R. Goethert

4.753J Structuring Low-Income Housing Projects in Developing Countries (A)

(Same subject as 11.463J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Examines relationship between housing needs and government-sponsored projects. Emphasis on costs recovery, affordability, replicability, user selection, and project administration. Extensive case examples provide bases for comparisons.
R. Goethert

4.755J Special Interest Group in Urban Settlements: SIGUS Workshops (A)

(Same subject as 11.465J)
Prereq.: Permission of Instructor
G (2)
Arr.

Interactive interdisciplinary workshops which focus on projects and practices on urban settlement issues in developing countries throughout the world. Participation by guest practitioners.
R. Goethert, N. Hamdi, R. A. Gakenheimer, B. Sanyal

4.767J Planning in Socialist Countries (A)

(Same subject as 11.417J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 11.417J.
T. Lee

4.770 Environmental Psychology (New)

Prereq.: —
U (1) HASS
3-3-6

Presents social science theories and methods that apply to human transactions with a wide range of environments. Focuses on development of applied research skills relevant to successful designing for human use, from urban to machine interface. Readings reinforce lectures and field work. Semester projects dovetailed with student's field of interest.
S. Howell

4.771 Behavior in the Built Environment

Prereq.: —
G (1)
3-3-6

Introduces behavioral science theories and methods as they relate to interactive affects of people in residential, working, and therapeutic settings. Readings supplement lectures and assigned fieldwork. Reading and interpretation of social science literature; application of research methods such as behavior mapping, interviewing, and perceptual measures in systematic evaluations of environments in use.
S. C. Howell

4.772 User Needs Programming (A)

Prereq.: 4.771
G (2)
3-0-6

Advanced seminar in selection and utilization of social science information in the formulation of architecture and planning programs. Current programming issues form basis of case studies. Stresses principles of information transfer and feedback in evaluation of existing programs and their built/occupied results. Representatives of public and private decision making agencies may participate.
S. C. Howell

4.781, 4.782 Research Topics in Architecture Studies (A)

Prereq.: 4.273
G (1, 2)
Arr.

Research work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Staff

4.795-4.799 Special Problems in Architecture and Social Change (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual and group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Staff

Visual Arts

4.802 Visual Form and Expression

Prereq.: —
U (2) HUM-D
3-0-6

Introduces the language of art and emphasizes experiencing the artist's process of seeing, thinking, and performing, with the objective of developing visual awareness, imagination, and creative insight. Gestalt theories of perception and art from the past and present clarify assignments involving manipulation of the visual elements that constitute the vocabulary of nonverbal expression.
Staff

4.821 Visual Projects I

Prereq.: —
U (1, 2) HASS
3-0-6

Emphasizes the interaction of media concepts and design principles in creating visual form, and explores the potential for new modes of artistic performance inherent in science and technology. Projects involve experimental manipulation of materials, tools, techniques, physical processes, natural forces, and optical phenomena as means for visual invention, organization, and expression.
Staff

4.823 Form and Design I

Prereq.: —
U (1) HASS
2-4-6

Studies the visual elements of form to understand the processes of form synthesis. Studio experiments and lectures on proportion, shape, rhythm, visual quality of materials, and three-dimensional composition. Emphasizes imagination and visual sensitivity, directed to enlarge the individual's ability to create an aesthetic form.
R. Filipowski

4.824 Form and Design II

Prereq.: —
U (2) HASS
2-4-6

Three-dimensional experiments and lectures on the organization of quantities; unit-to-volume relationships; modularity and form; volume and structure; surface structure of volume; space composition; point, line, plane composition; and sculptural composition. Emphasizes architectonic and sculptural aesthetic of form.
R. Filipowski

4.825 Form and Color

Prereq.: —
U (1, 2) HASS
3-0-6

Examines color in natural form. Experiments involving the color and form relationship to proportions, percentages, repetition, directions, quantity organization, structural order, angle position, and volume composition. A study to gain knowledge of color for the refinement of architectural form.
R. Filipowski

4.828 Special Problems in Visual Design

Prereq.: 4.821 or 4.824
U (1, 2)
Arr.

Supplementary work on individual and group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Staff

4.831 Art and the Environment (4.801)

Prereq.: —
U (1) HASS
3-0-6

Reviews art, architecture, and celebrations and their positions in workday, religious, and political life. Reconsiders the present position of art and redefines the artist's options in the contemporary environment. Examines fact and changes effected by current science and technology vis-à-vis our place in nature and history.
O. Piene

4.832 Environmental Art (4.831)

Prereq.: —
U (2) HASS
0-4-8

Design and planning of environmental art installations in given and chosen existing settings. Emphasizes daring ideas in conjunction with realistic approach and possibility for execution. Artistic means ranging from large-scale painting and graphic design to kinetic architecture and natural elemental growth-and-change systems and to sound and video installations and performances.
O. Piene

4.838 Special Problems in Environmental Art

Prereq.: 4.831
U (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
O. Piene

4.845, 4.846 Advanced Visual Design (A)

Prereq.: Permission of Instructor
G (1, 2)
0-9-12

Individual concepts, projects, design, and execution of installations, objects, and events in environmental art and performance involving elemental and science-technology means and media.
O. Piene

4.855-4.859 Special Problems in Environmental Art (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Special work on an individual or group basis using specific means such as video, holography, and multimedia. Registration subject to prior arrangement of subject matter and supervision by staff.
O. Piene

4.861 Life Drawing

Prereq.: —
U (1, 2)
0-3-3

Approaches life drawing, emphasizing the dynamic rather than realistic aspect of rendering. Encourages making impressions of the human figure by relying on creative instincts and natural ability to create illusions using the conte crayon and an eraser. Some exercises deal with precise observations and skill in graphic representation. May be repeated for credit.
N. Bichajian

4.862 Still-Life Drawing

Prereq.: —
U (1, 2)
0-3-3

Approaches still-life drawing, emphasizing light and shadow and linear and perspective renderings of varied subject matter. Value, color, texture, and form using conte, pen and ink, brush, and chalk to mix and create images. May be repeated for credit.
N. Bichajian

4.863 Advanced Figure Drawing

Prereq.: 4.861
U (1, 2)
0-3-3

Emphasizes the formal elements of line, mass, texture, and spatial development and the expressive, emotional value of the figure drawn on two-dimensional surfaces. Experimentation with a wide variety of techniques using a conte crayon and an eraser.
N. Bichajian

4.865 Basic Photography for Architects

(4.915)
Prereq.: Permission of Instructor
G (1, 2)
3-0-9

A basic approach to architectural photography including film processing, printing techniques, copy work, filtration, and metering. Technical information to better understand the relationship among film, camera, and light. Topics include the role of daylight and artificial light and their relation to forms, tone, and texture in picture taking, basic design, and composition. 35mm camera necessary.
N. Bichajian

Media Arts and Sciences

4.870 Words, Images, Graphics Tools, and Ideas

Prereq.: —
U (1) HASS
2-4-6

Introduces the spectrum of graphics ideas and tools available at the Visible Language Workshop. Public and personal ways of seeing, thinking, and communicating in visual and verbal modes, including making ideas visible, perception, and personal response. Uses a variety of traditional, electronic, and computational tools to explore both intellectual and expressive issues of communication. Projects, papers, and a final presentation are required. Enrollment limited. Lab fee.
M. Cooper, Staff

4.371 Graphics Communication Workshop

Prereq.: —
U (2) HASS
2-4-6

Thinking and communicating visually and sensorially by design. Investigates static and dynamic graphic principles in the design of images, graphics, and information through drawing, typography, symbols, diagrams, maps, photography, video, computer graphics, color, word and image organization, sound, and animation. Develops perspective and conceptual skills culminating in a coordinated multimedia presentation of issues and ideas. Projects, papers, and a final presentation are required. Enrollment limited. Lab fee.
M. Cooper, Staff

4.872 Creative Seeing

(4.901)
Prereq.: —
U (1) HUM-D
3-0-6

Creative Seeing presents experience with multiple ways of presenting and manipulating the world through visual means. Traditional, electronic, and computational media are explored. The aim is to allow students to experience and understand different levels of vision through personal discovery. Projects, papers, and a final project are required. Limited enrollment. Preference to freshmen and sophomores. Lab fee.
M. Cooper, Staff

4.874 Computers and Graphics Workshop Supplement (New)

Prereq.: 4.875 or 4.876
U (1, 2)
0-2-7

Supplemental work in computer graphics in the VLW.
M. Cooper, Staff

4.875 Computers and Graphics Workshop I

Prereq.: 4.870 or 4.871
U (1)
2-4-6

Integrated seminar-workshop researches issues relevant to the graphic synthesis of design practice, research, and artificial intelligence. The first semester addresses: 1. VLW computational resources and programming concepts; 2. Design issues in traditional and electronic environments; 3. Artificial intelligence concepts and issues. A minicourse in research methods and writing is included. Small projects, a term paper, and project are required. Enrollment limited, permission of instructor.
R. MacNeil, M. Cooper

4.876 Computers and Graphics Workshop II

Prereq.: 4.875
U (2)
2-4-6

This seminar-workshop is a continuation of 4.875.
R. MacNeil, M. Cooper

4.878, 4.879 Graphics/Imaging Media Projects

Prereq.: 4.870 or 4.871
U (1, 2)
Arr.

Special work on an individual or group basis combining research and projects of multidimensional graphics, typography, imaging, static or dynamic, 2- or 3-D, and audio in an intelligent electronic design environment. Registration subject to prior acceptance of project, supervision by VLW staff. Completion dependent on successful demonstration and documentation of semester's project.
M. Cooper, Staff

4.884 Computers and Graphics Workshop Supplement (A)

Prereq.: 4.885 or 4.886
G (1, 2)
0-2-7

Supplemental work in computer graphics in the VLW.
M. Cooper, Staff

4.885 Computers and Graphics Workshop I (A)

Prereq.: Permission of Instructor
G (1)
2-4-6

4.886 Computers and Graphics Workshop II (A)

Prereq.: 4.885
G (2)
2-4-6

Project-based survey introduces the computer as an expressive tool in image and word manipulation/synthesis. Graphical problem solving in PL1 and Magic6 using sample programs. Connections to traditional and experimental print forms using the Visible Language Workshop's full-color computer graphics system, color graphic arts scanner, plotter, small hardware projects in digital markmaking. Requires final project produced on VLW system and a software or hardware tool that can be installed as part of that system. Limited enrollment.
R. MacNeil, M. Cooper

4.887-4.889 Graphic Imaging Media Projects (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Special work on an individual or group basis combining research and projects of multidimensional graphics, typography, imaging, static or dynamic, 2- or 3-D, and audio in an intelligent electronic design environment. Registration subject to prior acceptance of project, supervision by VLW staff. Completion dependent on successful demonstration and documentation of semester's project.
M. Cooper, Staff

4.891 Creative Photography I

(4.921)
Prereq.: —
U (1, 2) HASS
4-4-4

Introductory subject covering a variety of traditional and electronic cameras, exposure and development of film, printing, and final presentation. Varied assignments encourage exploration of all aspects of creative photography. Assumes that possibilities for the growth of personal expression increase in relation to technological understanding and skills. Lab fee, limited enrollment.
M. Cooper

4.892 Creative Photography II

(4.924)
Prereq.: 4.891
U (2) HASS
3-0-9

Intermediate-level production subject emphasizing students' unique vision. Use of traditional and electronic imaging tools. Requires a substantial project. Weekly critiques, readings, and intensive study of related photographic and computer graphic works. Limited enrollment, lab fee required.
M. Cooper, Staff

4.893 Advanced Photography (A)

(4.927)
Prereq.: Permission of Instructor
G (1)
2-5-5

Project-oriented workshop in photographic imaging with traditional and electronic tools. Mature students pursue and develop their own unique styles. Explores advanced aesthetic and technical problems and concepts of evaluation. Limited enrollment, lab fee required.
M. Cooper, Staff

4.896 Special Projects in Photography

(4.928)
Prereq.: Permission of Instructor
U (1, 2)
Arr.

Traditional and electronic photographic imaging projects on an individual basis. Work in various imaging areas which are not included in regular subjects. Can include research topics coupled with projects. Registration subject to prior arrangements of topics, projects, and supervision.
M. Cooper, Staff

4.897 Special Advanced Projects in Photography (A)

(4.929)
Prereq.: Permission of Instructor
G (1, 2)
Arr.

More advanced topics for either individuals or groups. Traditional and electronic photographic imaging projects as the basis for work in various imaging areas which are not included in regular subjects. Can include research topics coupled with projects. Registration subject to prior arrangements of topics, projects, and supervision.
M. Cooper, Staff

4.904J Computer Graphics and Vision (A) (New)

(Same subject as 9.366J)
Prereq.: 4.911 or 9.36
G (2)
3-3-6

See description under subject 9.366J.
W. A. Richards, A. Pentland

4.906J Image Representation for Vision (A)

(Same subject as 9.358J)
Prereq.: Permission of Instructor
G (1)
2-0-7

Natural and artificial vision systems begin by transforming an image into a set of representations, thus choosing the "language" used at each stage of visual processing. This subject covers representations proposed in the context of human perception, neurophysiology, computer vision, image processing, and computer graphics. Topics include spatial frequency, tuning, scale in variance, and models for edges, surfaces, and textures.
E. H. Adelson

4.907 Artificial Intelligence and Cognitive Science (A) (New)

Prereq.: Permission of Instructor
G (1)
2-3-7

Discussion seminar covering a selection of readings at the intersection of artificial intelligence and cognitive science. Topics include perception, neural computation, learning, and reasoning.
A. Pentland

4.908, 4.909 Special Projects in Computers and Vision (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis on visual arts projects involving more than one medium. Registration subject to prior arrangement of subject matter and supervision by staff.
Staff

4.911 3-D Computer Graphics

Prereq.: —
U (1)
3-0-9

Overview of the techniques of computer image synthesis, including both hardware and software. Line drawing and color raster graphics. Homogeneous coordinates, hidden surface, and smooth-shading algorithms. Programming problems and a term project. Limited enrollment. Previous programming experience required.
D. Zeltzer

4.912 Advanced Computer Graphics (A)

Prereq.: Permission of Instructor
G (2)
4-0-8

Treats in-depth current research in 3-D computer graphics. Readings from recent papers. Significant term projects including an implementation, written report, and classroom presentation.
D. Zeltzer

4.919 Special Projects in Computer Graphics (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
D. Zeltzer

4.921J Digital Audio Processing (A)

(Same subject as 21.671J)
Prereq.: Permission of Instructor
G (1)
3-6-3

Audio signal processing for expressive communication. Analysis/synthesis of speech and music, linear-prediction, phase vocoders, digital sampling, mixing, editing, reverberation. Music representation, computer-generated scores, performer-like interpretation. Pitch detection, tracking of live performers, machine response. Building expressive workstations via realtime object-oriented audio processing. Assignments and synthesis projects.
B. Vercoe

4.922J Writing for Computer Performance (A)

(Same subject as 21.672J)
Prereq.: 4.921
G (2)
3-6-3

Music composition using digital audio as an expressive medium. Audio processing in specific musical contexts. Stylistic relationship between instrumental and electronic writing, and integration of these media as found in works of Davidovsky, Boulez. Directed composition of an original work for digital synthesis, and preparation for its performance in an end-of-term public concert.
B. Vercoe

4.925J Musical Aesthetics and Media Technology (A)

(Same subject as 21.685J)
Prereq.: Permission of Instructor
G (1)
3-3-3

In-depth exploration of contemporary concepts in music and media. Studies recent music that uses advanced technology, and the artistic motivations and concerns implied by the new media. Practical hands-on experience with computer music technology, with special emphasis on MIDI-based synthesizers and samplers and real-time performance systems. Term project required.
T. Machover

4.926J Projects in Media and Music (A)

(Same subject as 21.686J)
Prereq.: Permission of Instructor
G (2)
3-3-3

Current computer music concepts and practice. Project-based work on research or production projects using the Media Lab's computer music resources. Requires significant studio work and a term project.
T. Machover

4.929 Special Topics in Music and Cognition (A) (New)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Advanced work on current topics in music research and production. Individual or group basis. Registration subject to prior arrangement of subject matter and supervision by staff.
B. Vercoe

4.931 Digital Video (A)

Prereq.: Permission of Instructor
G (2)
2-0-7

Provides a technical introduction to video imaging, storage, and display devices, and their digital counterparts. Regards the video system as a general communications link capable of transmission of analog images as well as computer data, connected to image processing equipment as well as digital computers and displays. Topics: raster scan display architecture, anti-aliasing, optical storage, video encoding. Requirements include individual term projects.
A. Lippman

4.932 Conversational Computer Systems (A)

Prereq.: Permission of Instructor
G (1)
3-6-3

Methods of interacting with computer systems by voice, including speech synthesis, recognition, and digital recording techniques. Emphasis on human interface design issues, including extensive readings from current research literature, laboratory sessions, and a term project. Topics include human speech production and recognition, text to sound rules, synthesis of intonation, isolated and connected speech recognition, parsers and dialogue generation. Programming experience required except with permission of instructor.
C. Schmandt

4.939 Special Projects in Communications (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement of subject matter and supervision by staff.
A. Lippman

4.943 Learning Environments (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-6

Seminar to develop a framework for understanding the entry of new technologies — computers, video technologies, communications — into the process of learning. Reading covers a broad range of topics in human sciences, epistemology, and computer sciences; research projects, either self-initiated or assigned. May be repeated for credit.
S. A. Papert

4.945 Children as Builders of Their Own Cognitive Tools (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Knowledge acquisition from a constructivist point of view. The child examined as the constructor of his/her cognitive tools. Knowledge examined as the child's capacity to gain control over her/his environment.
E. Ackermann

4.948, 4.949 Special Topics in Learning Environments (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement and supervision by staff.
Staff

4.953 Holographic Imaging (Revised Content and Unit)

Prereq.: Permission of Instructor
U (1)
3-3-6

4.954 Holographic Imaging (A) (Revised Content and Unit)

Prereq.: Permission of Instructor
G (1)
3-3-6

A laboratory-based exploration of the principles, techniques, and applications of holography as a 3-D image communication medium, emphasizing white-light holograms. Lab fee. Limited enrollment.
S. Benton

4.956 Synthetic Holography

Prereq.: 4.954
G (2)
3-3-3

An introduction to the synthesis of holographic 3-D images from digital, video, and photographic data, and their applications. Limited enrollment.
S. Benton

4.958 Special Problems in Spatial Imaging (A)

Prereq.: 4.954
G (1, 2)
3-3-3

Advanced workshop in holography as an expressive medium, reflecting the points of view of visiting holographers. Limited enrollment.
S. Benton

4.959 Special Projects in Spatial Imaging (A)

Prereq.: 4.953 or 4.954
G (1, 2)
Arr.

Advanced spatial imaging and/or holographic work on individual or group basis. Registration subject to prior arrangement of subject matter and supervision by staff.
S. Benton

4.961, 4.962 Research in Media Technology (A)

Prereq.: —
G (1, 2, S)
Arr.

For research assistants in Media Technology, where the assigned research is approved for academic credit by the Department.
S. Benton

4.963 Preparation for S.M. Thesis (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Selection of thesis topic, definition of method of approach, and preparation of thesis proposal. Independent study supplemented by individual conference with faculty.
Staff

4.964 Media Arts and Sciences Doctoral Proseminar (A) (Revised Unit)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Explores the new and emerging technologies that are the basis of the interdisciplinary Media Arts and Sciences program. Members of workshop pursue work designed to elucidate and criticize their own presuppositions and methods. Required of Ph.D. candidates in the Media Arts and Sciences program. May be repeated for credit.
S. Papert

4.965 Preparation for Ph.D. Thesis (A)

Prereq.: —
G (1, 2)
Arr.

Selects thesis subject, defines method of approach, and prepares preliminary thesis outline. Independent study, supplemented by frequent individual conference with staff members. Restricted to doctoral candidates.
S. Benton

4.966-4.969 Special Topics in Media Technology (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
Staff

4.971 Introduction to Moviemaking

Prereq.: Permission of Instructor
U (1) HASS
4-6-2

Workshop in unscripted synchronous sound moviemaking with super-8 film and portable video. Emphasizes approaches to filming real life experience, while exploring moving images in their relation to sound. Introduces techniques of camerawork, sound recording, and editing with regard to theoretical considerations of subject presentation and modes of personal expression. Lab fee.
R. Leacock, G. Davenport

4.973 Intermediate Motion Picture Production

Prereq.: 4.971
U (2) HASS
4-6-2

Workshop in film/video production for students with some experience. Emphasizes refinement of production technique; introduces 16mm and broadcast video technology. Group work for final projects. Topics may include bio/autobiographical, time/space, performance and/or science movies.
R. Leacock, G. Davenport

4.974 Design Project in Film/Video Technology

Prereq.: Permission of Instructor
U (1, 2)
Arr.

Independent engineering project, involving electronic or mechanical modification of low-cost moviemaking systems, video-computer interface, audio and image processing, hardware design for special applications. Registration subject to prior arrangement of research topic and approval of instructor.
G. Davenport

4.975 Film and Video Production Technology

Prereq.: Permission of Instructor
U (1, 2)
Arr.

Introduction to theoretical and practical aspects of film and video production equipment from an engineering perspective. Emphasizes a hands-on analysis of mechanical and electronic components in 16mm and super-8 film, analog video, digital and analog sound equipment. Also covers timing and compatibility issues related to post-production systems. Students should be familiar with basic electronics and have some background in circuit design. Can be taken with 4.974.
G. Davenport

4.977 Special Projects in Television Production

Prereq.: Permission of Instructor
U (2)
Arr.

Supplementary work on individual or group basis in the production of a significant project for cable or broadcast television. Registration subject to prior arrangement of subject matter and supervision by staff.
R. Leacock

4.978 Independent Projects in Film/Video Production

Prereq.: Permission of Instructor
U (1, 2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement of subject matter and supervision by staff.
R. Leacock

4.981 Advanced Moviemaking Workshop (A)

Prereq.: Permission of Instructor
G (1)
4-6-2

Intensive advanced workshop in unscripted moviemaking. Combines a thorough review of sound, single and double system, super-8, and video technologies and production techniques with screening and discussing other filmmakers' work. Following initial exercises in sound, super-8, and video, students complete two short but significant movies, one in super-8, one in video. Average cost of supplies $300 per student. Required of all entering graduate students in Film/Video section.
G. Davenport

4.982 Advanced Moviemaking Workshop II (A)

Prereq.: 4.981
G (2)
4-6-2

Continuation of 4.981. Analysis of student work-in-progress as well as significant work by other filmmakers. Theoretical discussion of editing style in relation to overall movie structure. Consideraton of cinematic structures for polylinear movies. Students edit sequences shot by other filmmakers and complete one or two short movies. Meetings with visiting filmmakers. Required of all second-semester graduate students in Film/Video section.
R. Leacock, G. Davenport

4.988 Workshop in Elastic Movie Time (A)

Prereq.: 4.982
G (1, 2)
6-7-2

Intensive workshop in electronic image, sound, and time manipulations exploring new movie forms. Participants use the Film/Video group's video editing and research facility to create works that expand and contract motion picture time. Projects involve multiple edits of two movies and a presentation of possible applications of elastic time: multiple-media performance events, interactive movies, personalized editing.
G. Davenport

4.989 Independent Projects in Motion Picture Production (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Individual or group work of advanced and experimental scope. Registration contingent upon prior determination of subject matter and plan for treatment, as well as arrangement for staff supervision and project funding.
R. Leacock, G. Davenport

4.991 Introduction to the History of Film I

Prereq.: —
U (1) HASS
3-0-6

4.992 Introduction to the History of Film II

Prereq.: —
U (2) HASS
3-0-6

Views and discusses movies, particularly in light of technological innovation. Analyzes various film genres revealing the relation of the historical development of production technologies to film form and content. Requires final paper.
R. Leacock

4.999 Special Topics in Film History and Criticism (A)

Prereq.: 4.991
G (1, 2)
Arr.

Individual projects in film history and criticism. Prior arrangement and approval of instructor necessary.
R. Leacock

Course 5 Chemistry

5.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Program of research to be arranged by the student and a departmental faculty member. Department Coordinator: R. L. Danheiser.

5.03 Principles of Inorganic Chemistry I

Prereq.: 5.12
U (2)
4-0-8

Presents principles of chemical bonding and molecular structure, and their application to the chemistry of representative elements of the periodic system.
D. Seyferth, A. Davison

5.04 Principles of Inorganic Chemistry II

Prereq.: 5.03
U (1)
4-0-8

Systematic presentation of the chemistry of coordination compounds of the transition elements. Special emphasis placed on ligand field theory, to interpret the electronic spectra, magnetic properties, reaction mechanisms, structure, and stabilities of these inorganic complexes. 5.61 background encouraged.
A. Davison, R. R. Schrock

5.05 Principles of Inorganic Chemistry III

Prereq.: 5.03, 5.04
U (2)
3-0-9

Continued development of systematic inorganic chemistry of the elements. Application of valence theory and advances in structural chemistry to topics not covered in 5.03 and 5.04. Emphasizes synthesis and reactivity, metal complexes with n-π acceptor ligands, organometallic chemistry, and reactivity patterns of the heavier elements.
S. L. Buchwald, R. R. Schrock

5.065 Advanced Inorganic Chemistry (A)

Prereq.: 5.03
G (2) **Not to be offered 1989-90**
2-0-4

Extended treatment of some special topics of current interest in modern inorganic chemistry, organometallic compounds of non-transition elements; treatment in terms of modern electronic and structural theory. Alternate years.
D. Seyferth

5.11 Principles of Chemical Science

Prereq.: —
U (1, 2) SD
5-0-7

Introduction to chemistry, with emphasis on basic principles and their applications. Includes atomic and molecular electronic structure, thermodynamics, acid-base and redox equilibria, mechanisms, catalysis, and aspects of metal coordination chemistry and organic chemistry.
Term 1: *S. J. Lippard, R. J. Silbey*
Term 2: *R. W. Field, Staff*

5.12 Organic Chemistry I

Prereq.: 5.11
U (1, 2) SD
5-0-7

Introduction to organic chemistry. Development of basic principles to understand the structure and reactivity of organic molecules. Emphasis on substitution and elimination reactions and chemistry of the carbonyl group. Introduction to the chemistry of aromatic compounds.
Term 1: *D. S. Kemp*
Term 2: *G. A. Berchtold, F. D. Greene*

5.13 Organic Chemistry II

Prereq.: 5.11, 5.12
U (2)
5-0-7

Intermediate organic chemistry. Synthesis, structure determination, mechanism, and the relationships between structure and reactivity emphasized. Special topics in organic chemistry included to illustrate the role of organic chemistry in biological systems and in the chemical industry.
K. B. Sharpless, R. L. Danheiser

5.195 Interpretive Spectroscopy (A)

Prereq.: 5.13, 5.61
G (1)
3-0-6

Discusses spectrometric techniques and their application to identification of organic chemical compounds. Major emphasis on complementary use of infrared, nuclear magnetic resonance, and mass spectrometry. Also discusses instrumental and operational aspects of mass spectrometry.
K. Biemann, G. A. Berchtold

5.310 Laboratory Chemistry

Prereq.: 5.12
U (1, 2) LAB
2-8-2

Introduces experimental chemistry for students who are not majoring in Course V. Principles and applications of chemical laboratory techniques, including preparation and analysis of chemical materials, measurement of pH, gas and liquid chromatography, visible-ultraviolet spectrophotometry, infrared spectroscopy, electrophoresis, kinetics, data analysis, and elementary synthesis. Enrollment limited to 100 students in Term 1 and to 180 students in Term 2.
Term 1: *J. I. Steinfeld*
Term 2: *R. A. Alberty*

5.311 Introductory Chemical Experimentation

Prereq.: 5.12
U (1) LAB
2-8-2

First term of a three-term laboratory subject sequence for Course V majors. Experimental work emphasizes development of fundamental laboratory skills and techniques: volumetric and colorimetric analysis; preparation, purification, and characterization of chemical substances; and data analysis. Enrollment limited to 50 students. Registration in Course V or permission of instructor required.
S. T. Ceyer

5.32 Intermediate Chemical Experimentation

Prereq.: 5.310 or 5.311, *5.13, 5.60*
U (2)
0-12-3

Experimental work more advanced than in 5.310 or 5.311, emphasizing thermodynamic and kinetic measurements of organic reactions; and synthesis, purification, and analysis of organic compounds employing ir, nmr, uv, mass spectroscopy, and thin layer and gas-liquid phase chromatography.
K. Biemann

5.33 Advanced Chemical Instrumentation

Prereq.: 5.32, *5.61*
U (1)
0-15-6

Advanced experimentation, with particular emphasis on chemical synthesis and the fundamentals of quantum chemistry illustrated through molecular spectroscopy. Projects include NMR, ESR, and computer-interfaced IR spectroscopy; synthesis of organometallics under inert atmosphere; and synthesis of polymers.
K. A. Nelson

5.43 Organic Chemistry

Prereq.: 5.13
U (1)
4-0-8

Topics covered in this course may include organometallic chemistry, the chemistry of natural products, and biomolecules.
S. Buchwald, P. Lansbury

5.48J The Protein Folding Problem

(Same subject as 7.38J)
Prereq.: 7.05 or equivalent
G (2)
3-0-6

See description under subject 7.38J.
J. A. King

5.50 Bio-Organic Chemistry, Enzyme Reaction Mechanisms (New)

Prereq.: 5.13
U (2)
3-0-9

Study of the mechanisms of enzyme catalyzed reactions. Analysis of transformation of substrates to products with reference to kinetics and isotope effect measurements, sterochemistry and prosthetic group reactivity. Major transfer reactions, coenzyme catalyzed reactions, oxidation reactions, carbon-carbon bond forming reactions, elimination and racemization reactions.
J. Stubbe

5.511 Synthetic Organic Chemistry I (A)

Prereq.: *5.53*
G (1)
3-0-6

Introduction to the design of syntheses of complex organic compounds.
R. Danheiser

5.512 Synthetic Organic Chemistry II (A)

Prereq.: 5.511
G (2)
3-0-6

General methods and strategies for the synthesis of complex organic compounds.
S. Masamune

5.52 Advanced Biological Chemistry

Prereq.: Permission of Instructor
G (1)
2-0-4

Concepts and methods of biochemistry, with emphasis on quantitative aspects of problem analysis. Information: G. A. Petsko.

5.53 Molecular Structure and Reactivity (A)

Prereq.: 5.32, 5.13
G (1)
3-0-6

Reaction mechanisms in organic chemistry: types of mechanisms, reactive intermediates, methods of investigation, relation of structure to reactivity.
F. D. Greene, S. Masamune

5.54 Physical Organic Chemistry (A)

Prereq.: 5.53
G (2) **Next offered 1989-90**
2-0-4

Mechanisms of representative organic reactions in homogeneous liquid systems. Kinetic and other physical methods useful in studying organic reactions. Types of experimental evidence upon which current theoretical interpretations of reactivity are based.
D. S. Kemp

5.55 Organic Chemistry: Natural Products (A)

Prereq.: 5.511
G (2)
2-0-4

Chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis.
G. H. Büchi

5.56 Special Topics in Organic Chemistry (A)

Prereq.: 5.511, 5.53
G (2)
2-0-4

Advanced topics of special current interest.
G. Berchtold

5.57 Chemistry of Amino Acids, Peptides, and Proteins (A)

Prereq.: 5.13
G (2)
3-0-6

Synthesis of amino acids and peptides. Protective groups, amide formation, deprotection. Purification and manipulation of peptides. Correlations between structure and biological activity. Conformations of peptides. Peptides and proteins as reactive organic molecules. Relationships between structure and reaction mechanism for enzymes.
P. Lansbury

5.58 Introductory Bio-Inorganic Chemistry

Prereq.: 5.03
G (1)
3-0-6

Emphasizes structural, spectroscopic, and functional properties of transition metals coordinated to proteins. Overviews metabolism, storage, toxicity, and catalytic roles of metal ions, followed by description of the principal methods useful in metallobiochemistry. Considers in detail examples from the major categories of metalloproteins.
W. H. Orme-Johnson

5.595 Mechanisms in Energy Transduction

Prereq.: 7.03, 7.05, 5.60, or equivalent
G (2)
3-0-9

Biophysics and molecular biology of energy-transducing processes in bacteria and plants. Select review of literature on genes and proteins that mediate bioenergetic processes: photosynthetic light energy conversion; proton pumping; carbon dioxide, sulfate, nitrate, dinitrogen, and dioxygen reduction; hydrogen and methane production. Critical analysis of published papers and discussion of interdisciplinary approaches (genetics, structural studies, spectroscopy) used to relate structure to function. Application of basic research in energy studies to biotechnology.
D. C. Youvan, W. H. Orme-Johnson

5.60 Chemical Thermodynamics

Prereq.: *18.02*
U (1, 2) SD
4-0-8

Equilibrium properties of macroscopic systems. Basic thermodynamics — system, state of system, state variables. Work, heat, first law of thermodynamics, thermochemistry. Second and third law of thermodynamics — entropy, Gibbs function. Equilibrium phase rule, colligative properties of solutions, homogeneous and heterogeneous chemical equilibrium of reactions in the gas phase and solutions.
Term 1: *C. W. Garland, R. A. Alberty*
Term 2: *I. Oppenheim, K. A. Nelson*

5.61 Physical Chemistry

Prereq.: 8.02, 18.02
U (1) SD
4-0-8

Introductory quantum chemistry; elementary atomic spectra; particles and waves; wave mechanics; atomic structure and the Periodic Table; valence theory; experimental methods of determining molecular structure; structure of crystals and liquids; photochemistry.
R. Field

5.62 Physical Chemistry

Prereq.: 5.60 or 10.13
U (2)
4-0-8

Elementary kinetic theory and statistical mechanics; transpon properties of gases and liquids; rates of chemical reactions.
J. I. Steinfeld, S. T. Ceyer

5.64J Biophysical Chemistry

(Same subject as 7.71J)
Prereq.: 5.60, 7.05
U (1)
3-0-9

See description under subject 7.71J.
G. A. Petsko, P. Schimmel

5.68 Kinetics of Chemical Reactions (A)

Prereq.: 5.62
G (2) **Next offered 1989-90**
3-0-6

Experimental and theoretical aspects of reactive and inelastic molecular processes, including collision and transition — state theories, homogeneous reactions in gas and liquid phases, molecular beam scattering, information theory of kinetic processes. Case studies in chemical kinetics, including chemical lasers, atmospheric chemistry, combustion dynamics. Advanced undergraduate students need permission of instructor.
J. I. Steinfeld

5.70 Introduction to Statistical Thermodynamics (A)

Prereq.: 5.62
G (1)
3-0-6

Reviews classical thermodynamics and introduces elementary statistical mechanics, with applications to simple physical and chemical systems.
I. Oppenheim

5.72 Statistical Mechanics (A)

Prereq.: 5.70, 5.73, 18.075
G (2)
3-0-6

Principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, molecular distribution functions, and other topics in equilibrium statistical mechanics. Topics in thermodynamics and statistical mechanics of irreversible processes.
C. W. Garland

5.73 Introductory Quantum Mechanics I (A)

Prereq.: 5.61, 8.03
G (1)
3-0-6

Fundamental concepts of quantum mechanics: wave properties, uncertainty principle, Schrodinger equation. Basic applications to: harmonic oscillator, hydrogen atom, WKB method. Perturbation theory and variation method. Pauli principle and spin. Introduction and use of operator and matrix methods.
J. Waugh

5.74 Introductory Quantum Mechanics II (A)

Prereq.: 5.73, 18.075
G (2)
3-0-6

Time-dependent quantum mechanics, Liouville equations, relaxation phenomena, correlation functions, linear response theory, quantum transport, Anderson localization.
P. Phillips

5.80 Special Topics in Chemical Physics (A)

Prereq.: 5.70, 5.73
G (1, 2) **Next offered 1989-90**
Arr.

Advanced topics of special or current interest. The specific areas are announced in advance of each term. Information: R. J. Silbey.

5.89 Special Problems in Chemistry for Undergraduates

Prereq.: —
U (1, 2)
Arr.

Program of study to be arranged by the student and a departmental faculty member. A letter grade is given in this activity.
R. L. Danheiser

5.90 Special Problems in Chemistry (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

Directed research and study of special chemical problems. For graduate students only.
G. A. Berchtold

5.913 Seminar in Organic Chemistry (A)

Prereq.: —
G (1) [P/F]
1-0-2

5.914 Seminar in Organic Chemistry (A)

Prereq.: —
G (2) [P/F]
1-0-2

Discusses current journal publications in organic chemistry by graduate students and staff members. Consult S. Buchwald, P. Lansbury.

5.915 Seminar in Analytical Chemistry (A)

Prereq.: —
G (1) [P/F]
1-0-2

5.916 Seminar in Analytical Chemistry (A)

Prereq.: —
G (2) [P/F]
1-0-2

Discusses topics of current interest in analytical chemistry by graduate students and staff members.
K. Biemann

5.931 Seminar in Physical Chemistry (A)

Prereq.: —
G (1) [P/F]
1-0-2

5.932 Seminar in Physical Chemistry (A)

Prereq.: —
G (2) [P/F]
1-0-2

Discusses topics of current interest in physical chemistry by staff members and students.
Term 1: *P. Phillips*
Term 2: *J. Steinfeld*

5.941 Seminar in Inorganic Chemistry (A)

Prereq.: —
G (1) [P/F]
1-0-2

5.942 Seminar in Inorganic Chemistry (A)

Prereq.: —
G (2) [P/F]
1-0-2

Discusses current research in inorganic chemistry by graduate students and staff.
A. Davison

Course 6

Electrical Engineering and Computer Science

Basic Undergraduate Subjects

6.001 Structure and Interpretation of Computer Programs

Prereq.: —
U (1, 2)
5-3-7

Control of complexity in large programming systems. 1) Building abstractions: computational processes; higher-order procedures; compound data; data abstractions. 2) Controlling interactions: generic operations; self-describing data; message passing; streams and infinite data structures. 3) Meta-linguistic abstraction: interpretation of programming languages; machine model; compilation; embedded languages. Substantial weekly programming assignments are an integral part of the course. Enrollment may be limited.
H. Abelson, G. J. Sussman

6.002 Circuits and Electronics

Prereq.: 8.02 or 8.021 or 8.022 or 8.023, *18.03* or 18.06
U (1, 2) SD
4-2-9

Fundamentals of lumped networks, resistive elements and networks, energy storage elements, dynamics of first- and second-order networks, sinusoidal steady-state analysis, network equivalence theorems, electronic devices, circuits, and applications. Alternate week laboratory. Students with appropriate experience in electronic circuits may treat the 8.02 prerequisite as a corequisite. Enrollment may be limited.
J. K. Roberge

6.003 Signals and Systems

Prereq.: 6.001, 6.002
U (1, 2)
4-2-9

Laplace transform and its applications to networks and electronic systems including feedback. Description of linear time-invariant systems in the time and frequency domains; convolution, Fourier series and integrals. Uncertainty relations and sampling theorems. Discrete-time systems and signals. Applications to analog and digital filtering systems and modulation systems.
W. M. Siebert

6.004 Computation Structures

Prereq.: 6.001, 6.002
U (1, 2)
4-3-8

Introduces architecture of digital systems, emphasizing structural principles common to a wide range of technologies. Multilevel implementation strategies; definition of new primitives (e.g., gates, instructions, procedures, processes) and their mechanization using lower-level elements. Analysis of potential concurrency; precedence constraints and performance measures; pipelined and multidimensional systems. Instruction set design issues; architectural support for contemporary software structures.
S. A. Ward

6.012 Electronic Devices and Circuits

Prereq.: 6.002, 8.02
U (1, 2)
4-0-8

Modeling of electronic devices and analysis of nonlinear circuits. Physical electronics of semiconductor junction and MOS devices. Development of circuit descriptions for these devices; relation of electrical behavior to internal physical behavior, and limitations of circuit models. Development of incremental and large-signal techniques for analyzing circuits containing nonlinear devices. Analysis of signal-processing circuits that employ these devices, with examples chosen from switching circuits, single-ended and differential amplifiers, and integrated-circuit amplifiers.
C. G. Fonstad, Jr., A. C. Smith

6.013 Electromagnetic Fields and Energy

Prereq.: 6.002, 8.02
U (1, 2)
4-0-8

Maxwell's equations and the Lorentz force law. Quasistatic forms of Maxwell's equations. Studies of electro-quasistatic fields and their sources through solutions of Poisson's and Laplace's equations. Steady conduction and polarization. Charge relaxation. Magneto-quasistatic approximation; magnetic boundary value problems, magnetization, induction, current induced in stationary and moving conductors. Electric and magnetic forces derived from energy. Electromagnetic waves. Extensive use of engineering examples.
H. A. Haus

6.014 Electrodynamics

Prereq.: 6.013
U (1, 2)
4-0-8

Plane waves in three dimensions; radiation from elementary electric dipoles, current distributions, and arrays; diffraction and interference. Waves on continuous transmission lines, periodic structures, and dielectric and metallic waveguides; propagation and evanescence; energy flow and impedance matching. Phase and group velocity. Natural frequencies and modes of closed electromagnetic structures; coupling to resonant structures, loaded and unloaded Q's. Examples taken from the fields of acoustics, optics, and microwaves.
J. A. Kong, D. H. Staelin

6.018 Statistical Mechanics and Thermodynamics

Prereq.: 8.02, 18.03
U (2) SD
4-0-8

Statistical description of large physical systems. Laws of thermodynamics developed from statistical mechanics: phase space; entropy and temperature; work and heat; chemical potential; equations of state; free energies; heat engines and refrigerators; phase transitions. Quantum statistics: Fermi-Dirac and Bose-Einstein gases; statistics of electrons in metals and semiconductors; superfluidity and superconductivity; blackbody radiation.
Staff

6.021J Quantitative Physiology: Cells and Tissues

(Same subject as 2.791J, HST 541J)
Prereq.: 2.02 or 6.002 or 6.071, 8.02, 18.03
U (1)
4-2-6

Principles of mass transport, electrical signal generation, motility, and mechanical stability for biological membranes, cells, and tissues. Mass transport through membranes: diffusion, osmosis, chemically mediated, and active transport. Electric properties of cells: ion transport; equilibrium, resting, and action potentials. Intercellular communication: electrical and chemical junctions. Muscle contraction. Mechanics of connective tissue. Laboratory and computer exercises illustrate the concepts. For juniors and seniors.
T. F. Weiss, R. C. Lee, I. V. Yannas

6.022J Quantitative Physiology: Organ Transport Systems

(Same subject as 2.792J, HST 542J)
Prereq.: 2.20 or 6.013, *6.021J*
U (1)
3-2-7

Application of the principles of energy and mass flow to major organ systems of humans and other animals. Mechanisms of regulation and homeostasis. Anatomical, physiological, and pathophysiological features of the cardiovascular, respiratory, and renal systems. Emphasis on those systems, features, and devices that are most illuminated by the methods of physical sciences. Waiver of 6.021J by permission of instructor.
R. G. Mark, R. D. Kamm

6.023J Quantitative Physiology: Sensory and Motor Systems

(Same subject as 2.793J, 16.351J, HST 543J)
Prereq.: 2.02 or 6.003 or 16.30
U (2)
3-2-7

Studies of sensory and motor physiology, with objectives of establishing quantitative models. Peripheral signal processing in eye, ear, and vestibular systems. Physiology and psychophysics of audition, vision, orientation, and body stabilization. Organization of neuromuscular and proprioceptive systems at level of spinal cord reflex. Postural control and kinetics of movement. Supplemented by laboratory exercises. 6.021J recommended background.
L. S. Frishkopf, L. R. Young, R. W. Mann

6.033 Computer System Engineering

Prereq.: 6.004
U (1)
4-0-8

Topics on the engineering of computer software and hardware systems. Multilevel memory systems; naming and binding; privacy of information. Atomicity and coordination of parallel activities. Recovery and reliability. Networks and distributed systems. Techniques for controlling complexity. Impact of computer systems on society. Case studies of working systems and outside reading in the current literature provide comparisons and contrasts.
R. H. Halstead, Jr.

6.034 Artificial Intelligence

Prereq.: 6.001
U (1) SD
4-0-8

Studies the ideas and techniques that enable computers to behave intelligently. Case studies of programs that solve engineering problems like experts, diagnose disease, learn from experience, understand the visual environment, and engage in English discourse. The role of search, constraint propagation, logic, common sense, reasoning, and representation.
R. C. Berwick, T. Lozano-Perez, P. H. Winston

6.035 Computer Language Engineering

Prereq.: 6.170
U (2)
4-4-4

Analyzes issues associated with the implementation of higher-level programming languages. Fundamental concepts, functions, and structures of compilers. The interaction of theory and practice. Using tools in building software. Includes a multi-person project on compiler design and implementation.
J. V. Guttag, N. A. Lynch

6.036 Problem-Solving Paradigms

Prereq.: 6.034
U (2)
4-0-8

Investigates the basic paradigms for problem solving including the use (and misuse) of logic, procedural knowledge, debugging skills, and the reformulation of problems. Detailed study of natural deduction, pattern-directed procedures, and systems for reasoning effectively and efficiently within stereotypical situations. Examples drawn from mathematics, natural language comprehension, and programming. Applications of theoretical results to human problem solving and education.
C. E. Hewitt

6.037 Computer Graphics

Prereq.: 18.02
U (1)
3-0-9

Introduction to hardware, algorithms, and software of computer graphics. Topics include line generators, affine transformations, line and polygon clipping, splines, interactive technique, menus, orthographic and perspective projection, solid modeling, hidden surface algorithms, lighting models, and shading. Substantial programming experience required. Recommended for upperclass students only.
M. H. Raibert

6.041 Probabilistic Systems Analysis

Prereq.: 18.02
U (1, 2) SD
4-0-8

Modeling, quantification, and analysis of uncertainty. Formulation and solution in sample space. Random variables, transform techniques, simple random processes and their probability distributions, Markov processes, limit theorems, elements of statistical inference, and decision making under uncertainty. Interpretations, applications, and lecture demonstrations.
A. W. Drake

6.044J Computability, Programming, and Logic

(Same subject as 18.423J)
Prereq.: 18.063 or 18.310
U (1)
3-0-9

Introduction to logic and computability theory underlying programming. R.e. and recursive sets. Reducibility. Undecidable problems concerning programs, words, matrices, equations. Equational logic. Program schemes and first-order formulas. Recursion versus iteration. Elementary logic: completeness, incompleteness. Relation to theorem-proving and logic-programming. Program correctness.
A. R. Meyer

6.045J Automata, Computability, and Complexity

(Same subject as 18.400J)
Prereq.: 18.063 or 18.310
U (2)
4-0-8

Less mathematical and slower paced than 6.840J/18.404J. Introduces basic mathematical models of computation and the finite representation of infinite objects. Finite automata and regular languages. Pushdown automata and context-free languages. Turing machines and their variants. Partial recursive functions and grammars, Church's Thesis. Undecidability, languages, grammars, and combinatorial systems. Reducibility and completeness. Time complexity and NP-completeness.
S. Micali

6.046J Introduction to Algorithms

(Same subject as 18.410J)
Prereq.: 6.001, 18.063 or 18.310
U (1, 2)
4-0-8

Techniques for the design and analysis of efficient algorithms, emphasizing methods useful in practice. Topics include sorting; data structures for sets: trees, heaps, hashing. Graph algorithms: shortest paths, depth-first search, network flow. Computational geometry. Integer arithmetic: GCD's, primality testing. Fast Fourier transform. Multiplication of polynomials. Dynamic programming. Linear programming. Parallel and distributed algorithms.
S. Goldwasser, B. Awerbuch

6.047J Algorithmic Algebra and Number Theory

(Same subject as 18.421J)
Prereq.: 18.06 or 18.710, 18.063 or 18.310 or 18.703
U (2) **Not to be offered 1989-90**
3-0-9

See description under subject 18.421J.
S. Goldwasser, H. Rogers, Jr.

6.048J Graph Algorithms

(Same subject as 18.431J)
Prereq.: 18.310 or 18.314 or 18.063
U (2) **Not to be offered 1989-90**
3-0-9

See description under subject 18.431J.
D. B. Shmoys

6.061 Introduction to Electric Power Systems

Prereq.: 6.002, 6.013
U (S)
3-0-9

Fundamentals of energy-handling electric circuits and electromechanical apparatus. Modeling of magnetic field devices and description of their behavior using appropriate models. Simplification of problems using transformation techniques. Power electric circuits, magnetic circuits, lumped parameter electromechanics, elements of linear and rotating electric machinery. Modeling of synchronous, induction, and dc machinery.
J. L. Kirtley, Jr.

6.071 Introduction to Electronics

Prereq.: *8.02*,18.01
U (1, 2) SD
4-2-6

Introductory subject suitable for students with little or no previous background in electronics. Elementary network theory, diode and transistor circuits, analysis and design of analog and digital circuits. Examples emphasize uses of electronics in experimental science. Alternate week laboratory.
L. D. Braida

6.074 Introduction to Communications Systems

Prereq.: 6.003; *6.041* or *18.313* or *18.440*
U (1)
3-0-9

Introduces basic approaches utilized in communications systems. Description of signals and noise in the frequency domain. Analog and digital methods of modulation, demodulation, multiplexing, and transmission. Signal-to-noise ratios and error probabilities as measures of system performance.
R. S. Kennedy

Undergraduate Laboratory Subjects

6.100 Electrical Engineering and Computer Science Laboratory

Prereq.: —
U (1, 2, S)
Arr.

Individual experimental work related to electrical engineering and computer science not covered by other subjects. Student must make arrangements with a project supervisor and file a proposal endorsed by the supervisor. Department approval required. Written report to be submitted upon completion of work. If 6.100 is used to satisfy Departmental Laboratory Requirement, student must register for 12 units of laboratory credit in the term the work is done. Consult Department Undergraduate Office early in the term.
L. A. Gould

6.101 Introductory Analog Electronics Laboratory

Prereq.: 6.002 or 6.071
U (1, 2) LAB
3-8-1

Introductory experimental laboratory involving design and construction of electronic analog and digital circuits. Introduces electrical measuring and display instrumentation. Studies the operation and use of modern electronic devices. Independent project on design and construction of a practical electronic circuit. Project includes the conceptual design phase, generation of the circuit schematic and parts list, construction and testing of the circuit, and successful demonstration that original objectives have been met.
C. D. Paton, J. K. Roberge

6.111 Introductory Digital Systems Laboratory

Prereq.: 6.002 or 6.071
U (1, 2) LAB
3-7-2

Lectures and labs on digital logic, flipflops, PALs, counters, timing, synchronization, finite-state machines and microprogrammed systems prepare students for the design and implementation of a final project of their choice, e.g., games, music, digital filters, graphics, etc. Possible use of project report for Phase II. Six extra units possible via adding 6.919 after project proposal.
J. L. Kirtley, Jr., D. E. Troxel

6.115 Microcomputer Project Laboratory

Prereq.: 6.111
U (1)
3-7-2

Explores the use of microprocessors as elements in larger systems. Lectures cover microprocessor architectures and assembly languages, LSI peripheral devices, interfacing single-chip and special-purpose microcomputers, design and debugging aids, communication strategies, and multiprocessor systems. Exercises: assembly language, analog interfacing, and digital signal processing; microcontroller networks and multiprocessor systems. Major project: the design, construction, programming, and testing of a system using microprocessors as processing elements. Limited enrollment.
R. D. Thornton

6.121J Bioelectronics Project Laboratory

(Same subject as HST 575J)
Prereq.: 6.002 or 6.071
U (2) LAB
2-8-2

Project Laboratory in electronic instrumentation, interfacing the analog and digital world. Students specify design, implement, and evaluate biomedical instruments, including several interrelated analog and digital subsystems. Extensive use of integrated analog circuits and a microprocessor. Classroom development of analytic models for complex functional components and the measurement process in the context of a longitudinal laboratory project. Written report will meet the requirements of Phase II writing.
S. K. Burns, R. G. Mark

6.141 Energy and Electromechanical Systems Project Laboratory

Prereq.: 6.012 or 6.013
U (1, 2) LAB
0-10-2

Independent laboratory work involving electromechanical systems, power electronics, high-voltage systems, rotating electric machinery, bioelectromechanics, energy systems, and control. Student's choice of project is either from a list of suggested topics or developed by student in conjunction with instructor.
S. D. Umans

6.142 Microcomputer Control of Dynamic Systems

Prereq.: 6.001, 6.003
U (2)
2-7-3

Microcomputer-based control system laboratory. Lectures: analysis and design of sampled-data control systems, microcomputer-based control system implementation, and dynamic system control objectives. Laboratory experiments and term project on design and hardware/ software implementation of microcomputer-based control systems. Typical projects: control of ac and dc motors, power electronic circuits, and magnetic levitators. Limited to 25.
J. H. Lang

6.151 Semiconductor Devices Project Laboratory

Prereq.: 6.701J or 6.150J
U (2) LAB
0-12-0

Student use of the Microelectronics Laboratory facilities for individual or team projects in the area of design, fabrication, modeling, and characterization of individual MOS or bipolar devices, and of integrated circuits using these devices. Each term, the project topics are selected to fit the general areas of development in the Laboratory. Enrollment limited.
C. G. Sodini, L. R. Reif

6.161 Modern Optics Project Laboratory

Prereq.: 6.013, 6.003
U (1) LAB
2-8-2

Lectures, laboratory exercises, and projects in modern optics. Topics: polarization properties of light, reflection and refraction, coherence and interference, Fraunhofer and Fresnel diffraction, imaging and transforming properties of lenses, spatial filtering, coherent optical processors, holography, optical properties of materials, lasers, nonlinear optics, electrooptic and acoustooptic materials and devices, optical detectors, fiber optics, and optical communication. Seniors may use this laboratory to find a thesis.
C. Warde

6.162 Image Transmission Systems Project Laboratory

Prereq.: 6.012
U (1, 2) LAB
0-12-0

Students use the Image Processing Laboratory facilities of the Cognitive Information Processing Group in RLE or the Media Laboratory (Advanced TV Research Program) for projects related to picture transmission or reproduction systems. Facilities available for computer simulation studies as well as hardware projects. Possible topics: image enhancement and compression, implementation of image processing algorithms in hardware, image processing software development.
W. F. Schreiber

6.163 Strobe Project Laboratory

Prereq.: —
U (1, 2) LAB
2-8-2

A project laboratory for experiments, dealing mainly with the characteristics of electronic flash sources of light and their applications to photography and measurement problems. A program of experimentation concerned with electronic flash, organized with each group of students at the start of the term. Sign advance reservation list in room 4-405.
H. E. Edgerton, C. E. Miller

6.170 Laboratory in Software Engineering

Prereq.: 6.001
U (1, 2)
3-6-3

Introduces concepts and techniques relevant to the production of large software systems. Students taught a programming method based on the recognition and description of useful abstractions. Topics: programming methodology; procedural, data, and control abstractions; specifications; top down design, implementation, and testing. Several programming projects of varying size undertaken by students working singly and in groups.
J. V. Guttag, B. H. Liskov

6.182 Psychoacoustics Project Laboratory

Prereq.: —
U (2) LAB **Not to be offered 1989-90**
3-4-5

Introduces the methods used to measure human auditory abilities. Discusses auditory function, principles of psychoacoustic measurement, models for psychoacoustic performance, and experimental techniques. Project topics: absolute and differential auditory sensitivity, operating characteristics of human observers, span of absolute judgment, adaptive measurement procedures, scaling sensory magnitudes. Oral presentation and written report. Knowledge of probability helpful. Alternate years.
L. D. Braida

Advanced Undergraduate Subjects and Graduate Subjects by Area

Systems Science and Control Engineering

6.201 Introduction to Dynamic Systems

Prereq.: 6.003, 18.06
U (1)
3-0-9

Introduces modern system theory, with applications to control, signal processing, related areas. Topics: linear equations; least-norm and recursive least-square-error solutions. State space models of discrete- and continuous-time multi-input-output systems. Linear time-invariant systems: controllability, observability, modes, minimality, transfer function matrices, compensators, state feedback, optimal regulation, observers, frequency domain design. Introductory ideas on nonlinear systems and optimal control.
G. C. Verghese, S. K. Mitter

6.231 Dynamic Programming and Stochastic Control (A)

Prereq.: 6.041 or 18.313 or 18.440
G (2)
3-0-9

Introduces sequential decision making via dynamic programming. Unified approach to optimal control of stochastic dynamic systems and Markovian decision problems. Applications from control theory and operations research include linear-quadratic problems, inventory control, and resource allocation models. Optimal decision making under perfect and imperfect state information. Certainty equivalent and open loop-feedback control, self-tuning controllers. Infinite horizon problems, successive approximation, policy iteration.
D. P. Bertsekas

6.233J Multivariable Control Systems I (A)

(Same subject as 2.154J, 10.28J, 13.481J, 16.341J)
Prereq.: 2.14 or 6.302 or 10.35 or 16.30
G (1)
4-0-8

Integrated state-space and frequency domain description of linear multivariable feedback control systems based on models of physical processes. Stability, robustness, and performance specifications via singular values. Multivariable system analysis; stability, controllability, observability, poles and zeros, modal properties. Closed-loop stability, multivariable Nyquist criterion, and singular-value based robustness tests. Impact of unstable poles, nonminimum-phase zeros, and time-delays. Computer-aided homework.
M. Athans, J. K. Hedrick, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

6.234J Multivariable Control Systems II (A)

(Same subject as 2.155J, 10.29J, 13.482J, 16.342J)
Prereq.: 6.233J
G (2)
4-0-8

Computer-aided design methodologies for synthesis of multivariable feedback control systems. Performance and robustness trade-offs. Model-based compensators; separation properties. Linear-quadratic and Kalman filter designs. Integral control and other dynamic augmentation. Linear-quadratic-gaussian compensators with loop transfer recovery. Other design methodologies. Model and compensator simplification. Nonlinear effects. Computer-aided design homework using models of physical processes.
M. Athans, J. K. Hedrick, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

6.238 Dynamics, Estimation, and Control of Electrical Machine Systems (A)

Prereq.: 6.201 or 6.233J
G (2) **Next offered 1989-90**
3-0-9

Control theory approach, aimed at robotics, traction, and similar applications. Dynamic models for electrical machines and power electronic circuits; transformations; time-invariant, periodically varying, and sampled data models. Time and frequency scale decomposition. State-space averaging. Lyapunov stability methods; instability phenomena. Parameter estimation; (adaptive) state observers. Linear and nonlinear state feedback; field-oriented and sliding-mode control; adaptive and optimal control. Implementation. Alternate years.
J. H. Lang, G. C. Verghese

6.241 Dynamic Systems (A)

Prereq.: 6.003, 18.06
G (1)
3-0-9

Graduate introduction to modern system theory. Meets with 6.201, but requires completion of additional or alternative readings, problems, and tests.
G. C. Verghese, S. K. Mitter

6.242 Advanced Linear Control Systems (A)
(Revised Content)

Prereq.: 18.06, 6.241 or 6.201 or 6.233J
G (2)
3-0-9

Introduction to uncertain multivariable control systems, modeling assumptions and objectives. Stability of linear time invariant systems, coprime factorization, parametrization of all stabilizing compensators. Design using H_2, $H\infty$ L^1 -optimization. Robust performance, structure singular values.
M. Dahleh

6.243 Theory of Nonlinear Systems (A)

Prereq.: *18.100*, 18.06, 6.241 or 6.201 or 6.233J
G (1) **Not to be offered 1989-90**
3-0-9

Introduces nonlinear dynamical systems, with emphasis on stability theory. Solvability of nonlinear equations. Dynamical systems in input/output and in state space form. Feedback systems. Input/output stability concepts. Stability criteria based on the small loop-gain theorem and on passivity conditions. Circle criterion, Popov's criterion, and other frequency-domain stability criteria. Lyapunov stability theory. Dissipative systems. Alternate years.
S. K. Mitter, J. L. Wyatt, Jr.

6.251J Introduction to Mathematical Programming (A)

(Same subject as 15.081J)
Prereq.: 18.06
G (1, 2)
3-0-9

A first subject in mathematical optimization emphasizing both methodology and the underlying mathematical structures. Covers linear programming and related topics: the simplex method, duality theory, sensitivity analysis, network flow algorithms, decomposition, integer programming, and polyhedral geometry.
R. G. Gallager, R. M. Freund

6.252J Nonlinear Programming (A)

(Same subject as 15.084J)
Prereq.: 18.06, 18.100
G (2)
3-0-9

A unified analytical and computational approach to nonlinear optimization problems. Unconstrained optimization methods include gradient, conjugate direction, Newton, and quasi-Newton methods. Constrained optimization methods include feasible directions, projection, and Lagrange multiplier methods. Convex analysis, Lagrangian relaxation, nondifferentiable optimization, and applications in integer programming. Comprehensive treatment of duality theory. Applications drawn from control, communications, power systems, and resource allocation problems.
D. P. Bertsekas, J. F. Shapiro

6.255 Computation and Communication in Distributed Systems(A)

Prereq.: 18.06, 6.041
G (1) **Not to be offered 1989-90**
3-0-9

Parallel and distributed algorithms in fast parallel computation and data communication networks. Basic communication tasks in regular processor architectures. Parallel algorithms (direct and iterative, synchronous and asynchronous) for linear and nonlinear equations, optimization, dynamic programming, and network flow problems. Algorithms for controlling the operation of data networks and asynchronous computing systems: synchronization, termination detection, resource scheduling, routing and information broadcasting. Alternate years.
J. Tsitsiklis

6.262 Discrete Stochastic Processes (A)

Prereq.: 1.07 or 6.041 or 6.431 or 18.313
G (1)
3-0-9

Review of probability and laws of large numbers; Poisson counting process and renewal processes; Markov chains (including Markov decision theory), branching processes, birth-death processes, and semi-Markov processes; continuous-time Markov chains and reversibility; random walks and large deviations; applications from queueing, communication, control, and operations research.
R. G. Gallager, R. C. Larson, A. W. Drake

6.263 Data-Communication Networks (A)

Prereq.: 6.041 or 18.313
G (1)
3-0-9

Modeling of the control processes in computer and data communication networks. Develops and utilizes elementary concepts from queueing theory, algorithms, linear and nonlinear programming to study the problems of line and network protocols, distributed algorithms, quasi-static and dynamic routing, congestion control, deadlock prevention, local networks, and radio and satellite multi-access schemes.
D. P. Bertsekas

6.264J Queues: Theory and Applications (A)

(Same subject as 15.072J)
Prereq.: 6.262 or 6.432 or 15.073J
G (2)
3-0-9

Modeling and analysis of queueing systems, with applications in communications, manufacturing, operations research, computers, service industries, transportation, and urban systems. Simple Markovian queues, networks of queues, non-Markovian single and multi-server queues, priority queues, bounds and approximations, statistical inference. Leads to research opportunities.
P. A. Humblet, J. Keilson, R. C. Larson

6.281J Logistical and Transportation Planning Methods (A)

(Same subject as 1.203J, 11.526J, 13.665J, 15.078J, 16.76J)
Prereq.: 6.431, 15.075
G (1)
3-0-9

See description under subject 1.203J.
R. C. Larson, A. I. Barnett, A. R. Odoni, H. N. Psaraftis

6.291 Seminar in Systems, Communications, and Control Research (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

A seminar dealing with advanced topics in systems, communications, and control. Selected topics according to student and instructor interest. See instructor for specific topics to be offered in a particular term.
S. K. Mitter

Electronics, Computers, and Systems

6.301 Solid-State Circuits

Prereq.: 6.012
U (1)
3-3-6

Analysis and design of transistor circuits, based directly on the semiconductor physics and transistor circuit models developed in 6.012. High-frequency and low-frequency design calculations and simulation of multistage transistor circuits. Trans-linear circuits. The charge-control model. Introduction to operational-amplifier design and application. Some previous laboratory experience assumed.
J. K. Roberge, H. S. Lee

6.302 Feedback Systems

Prereq.: 6.003 or 2.02
U (2)
4-2-6

Introduction to design of feedback amplifiers and automatic control systems. Properties and advantages of feedback systems. Time-domain and frequency-domain performance measures. Stability and degree of stability. Root locus method. Nyquist criterion. Frequency-domain design. Compensation techniques. Sampled-data feedback systems. Application to electronic, electromechanical, and other physical systems. Some previous laboratory experience with electronic systems is assumed.
L. A. Gould

6.311 Telephony

Prereq.: 6.002 or 6.071 or 6.101
U (2)
2-0-4

Reviews current telephone technology. Examines the sequence of events occurring as a call is originated, connection made, and call completed for commonly used systems including manual switchboards, step-by-step, crossbar, and ESS offices. Interoffice connection, signal methods, and traffic problems. Technical and economic characteristics of equipment used for voice and data communications. Tours of representative facilities arranged.
S. K. Burns

6.312 Acoustics

Prereq.: 6.002
U (1)
3-1-8

Sound generation and propagation in elastic media. Simple sources and arrays of sources. Derivation of lumped parameter acoustical elements and circuits from solutions of wave equations. Radiation impedance. Conversion among acoustical, electrical, and mechanical energy. Modeling and analysis of electroacoustical devices such as microphones and loudspeakers. Sound in rooms. Interaction of sound and humans.
A. G. Bose

6.313 Contemporary Computer Design

Prereq.: 6.004
U (1)
3-0-9

Computer arithmetic; high-speed logic design and packaging; clocking strategies; pipelined computer techniques; microprogramming vs simple instruction sets; cache and paging design; datatyping, hardware support for garbage collection; MIMD/SIMD parallel computers; interprocessor communications technologies.
T. F. Knight, Jr.

6.331 Advanced Circuit Techniques (A)

Prereq.: 6.301, 6.302
G (1) **Next offered 1989-90**
3-2-7

Following a brief classroom discussion of relevant principles, each student completes the paper design of several advanced circuits such as multiplexers, sample-and-holds, gain-controlled amplifiers, analog multipliers, digital-to-analog or analog-to-digital converters, and power amplifiers. One of each student's designs may be presented to the class, and one may be built and evaluated. Associated laboratory emphasizing the use of modern analog building blocks. Enrollment limited. Permission of instructor required. Alternate years.
J. K. Roberge

6.332 Advanced Instrumentation Electronics (A)

Prereq.: 6.003
G (1)
3-0-9

Modern instrumentation circuits, transduction. Deterministic and statistical models. Emphasis on analog-digital circuits with microprocessor controllers. Case-study approach: team design, implementation, and presentation of prototype instruments such as op-amp tester, noise-measurement, thermal, electrochemical, optical measurement systems. Topics: linear circuits, op-amps, filters, differential amplifiers, synchronous detectors, phase-locked loops, sampling, quantization, microprocessor interface and control.
S. K. Burns, J. C. Weaver

6.333 Electronic Circuits (A)

Prereq.: 6.003
G (2)
3-0-9

Theory, analysis, and design of linear and nonlinear electronic circuits, emphasizing the use of computers to solve symbolic and numerical circuit problems. Topics: direct and interactive methods of circuit analysis, transformations and simplifications, computer simulation, fundamental limitations, and optimal design. Examples: amplifiers; oscillators; VLSI; feedback; power electronics; circuit analogs for field and electromechanical systems.
R. D. Thornton

6.334 Power Electronics (A)

Prereq.: 6.012, 6.013
G (2)
3-0-9

The application of electronics to energy conversion and control. Electrical and thermal characteristics of power semiconductor devices — diodes, bipolar and field effect transistors, and thyristors. Magnetic circuits. Active and passive filtering techniques. Emphasizes device limitations, circuit techniques,computer-aided analysis and design, and system control. Application examples include controlled rectifiers, high-frequency inverters, dc-dc conversion, and motion control. Assumes background in elementary device physics.
J. G. Kassakian, M. F. Schlecht

6.335 Fundamental Theory of Nonlinear Networks (A)

Prereq.: 6.003, 18.06
G (2) **Not to be offered 1989-90**
3-0-9

Network topology: graph theory, Tellegen's theorem, colored arc lemma, applications. Algebraic n-ports. Circuit properties: passivity, losslessness, reciprocity, monotonicity. Resistive networks: uniqueness, no-gain, sensitivity and extremum principles. Dynamic networks: state equations, differential equation theory, Lyapunov stability. Current topics and applications. Recommended prerequisite: 6.201. Alternate years.
J. L. Wyatt, Jr.

6.336 Numerical Simulation of Large-Scale Circuits (A)

Prereq.: 6.003, 18.06
G (1) **Next offered 1989-90**
3-0-9

Network equation formulation techniques: nodal, modified nodal, and sparse tableau analysis. Methods for solving linear and nonlinear algebraic systems: LU decomposition, sparse matrices, Newton algorithms, and secant methods. Numerical methods for stiff differential equation systems: stability of multistep discretization methods and truncation error timestep control algorithms. Techniques for very large problems: decomposition methods, relaxation algorithms, semi-implicit and multirate integration techniques. Alternate years.
J. K. White, J. L. Wyatt, Jr.

6.341 Digital Processing of Signals (A)

Prereq.: 6.003, 18.075 or 18.04
G (1, 2)
4-0-8

Representation, analysis, and design of discrete time signals and systems. Z-transforms and the discrete Fourier transform. Difference equations. The fast Fourier transform (FFT) algorithm. High-speed convolution. Time- and frequency- domain design techniques for recursive (IIR) and nonrecursive (FIR) systems. Finite wordlength effects. Additional topics may include homomorphic signal processing, Hilbert transforms, parametric signal modeling, power spectrum estimation, and applications to speech and image processing.
A. V. Oppenheim

6.343 Digital Speech Processing (A)

Prereq.: 6.341
G (2) **Not to be offered 1989-90**
4-0-8

Applications of digital techniques to the processing of speech signals. Time- and frequency-domain models for speech processing. Speech analysis techniques, including homomorphic, linear prediction, and short-time Fourier analyses. Principles of speech bandwidth compression, speech synthesis, and speech recognition. Survey of applications in the area of human-machine communication, including voice-response systems and speech recognition systems. Alternate years.
V. W. Zue

6.344 Two-dimensional Signal and Image Processing (A)

Prereq.: 6.341
G (2) **Next offered 1989-90**
3-0-9

Representation, analysis, and design of two-dimensional signals and systems. Two-dimensional Fourier transform, z-transform, discrete Fourier transform, and fast Fourier transform algorithms. Image processing basics. Image enhancement. Image restoration. Image coding. Alternate years.
J. S. Lim

6.346 Architectures for Digital Signal Processing (A)

Prereq.: 6.341, 6.823
G (1) **Not to be offered 1989-90**
3-0-9

Interrelationships between algorithm design and special-purpose computer architectures for digital signal processing. High-performance computers. Linear algebra algorithms and machines. Orthogonal transformations. Filter, Convolution and Fast Transform architectures. Compilation of algorithms into architectures. Image processing and local neighborhood operators. SIMD and MIMD designs. Term paper or project required. Alternate years.
B. R. Musicus

6.361 Image Processing (A)

Prereq.: 6.003
G (1)
3-0-9

Optical, electrooptical, electronic, and computer image processing techniques with applications to image restoration, quality improvement, and efficient coding for storage or transmission. Mathematical description of images. Relevant properties of human vision. Measures of quality. Scanning, sampling, and quantization. Fourier analysis and linear spatial filtering. Nonlinear processing. The halftone process. Technology of facsimile, television, and printing systems. Color. Term paper or project required.
W. F. Schreiber, A. N. Netravali

6.371 Introduction to VLSI Systems (A)

Prereq.: Permission of Instructor
G (1, 2)
3-3-6

Provides background in integrated devices, circuits, and digital subsystems needed for design and implementation of integrated systems. Design methodology, use of ratioed design rules and library modules, symbolic layout languages, computer-aided design techniques. Students required to complete, through layout, the design of a digital subsystem in NMOS or CMOS. Selected projects form a multi-project chip set, leading to wafers available after the end of the term for packaging and testing by the student. Limited enrollment.
J. Allen

6.372 Design and Analysis of VLSI Circuits (A)

Prereq.: 6.012, 6.371
G (2)
3-0-9

Design and analysis of digital MOS VLSI circuits. Topics: methodology design; device and interconnect physics; noise and tolerancing; noise margins; worst-case design; logic-gate dynamics; delay optimization; specialized circuit forms; clocking; VLSI micro-architecture. Emphasizes analytical and CAD techniques for high-performance circuit design. Limited enrollment.
T. F. Knight, Jr.

Probabilistic Systems and Communication

6.431 Applied Probability

Prereq.: 18.02
G (1, 2)
4-0-8

Meets with 6.041. Requires the completion of additional advanced home problems.
A. W. Drake

6.432 Stochastic Processes, Detection, and Estimation (A)

Prereq.: 6.003, 6.041 or 6.431 or 18.313
G (1, 2)
4-0-8

Fundamentals of detection, estimation, and stochastic processes of importance in communication, control, and signal processing. Review of probability and introduction of vector notation for sets of random variables. Principles of hypothesis testing and parameter estimation. Introduction to stochastic processes in continuous and discrete time. Correlation functions, power spectra and linear systems with stochastic inputs. Series expansions of processes. Signal detection and parameter estimation from noisy observations. Wiener filtering.
J. H. Shapiro, A. S. Willsky

6.433 Recursive Estimation (A)

Prereq.: 6.201 or 6.233J or 6.241, 6.432
G (2)
3-0-9

State-space based theory of dynamic estimation in discrete and continuous time. Linear state-space models driven by white noise. Kalman filter and its properties. Implementation issues, including the solution of the Riccati equation, the square-root filter, and efficient algorithms for the Kalman gain. Optimal smoothing for linear systems. Nonlinear filtering and the extended and second-order Kalman filters.
A. S. Willsky

6.435 System Identification (A)

Prereq.: 6.003, 6.041 or 6.431 or 18.313
G (1) **Next offered 1989-90**
3-0-9

Determination of valid mathematical models for physical and social systems, using observations of their behavior. Different philosophies of modeling; state space, time series. Multiple input-output, nonlinear, and time varying systems. Parameter estimation algorithms: full information maximum likelihood, least squares. Parameter identifiability. Model validation; statistical hypothesis testing, reasonability. Bad data-anomaly detection, robust estimation. Discussion of available software packages. Alternate years.
Staff

6.441 Transmission of Information (A)

Prereq.: 6.041 or 6.431 or 6.432 or 18.313
G (2)
3-0-9

Introduces the quantitative study of information, with emphasis on concepts fundamental to the engineering of reliable, efficient communication systems. Mathematical definition of information and study of its properties; efficient representation of message sources; communication channels and their capacity; coding for reliable transmission of data over noisy channels. Additional topics of interest such as representing data and control information in data communication networks are included.
R. G. Gallager

6.450 Communication Systems

Prereq.: 6.003; 6.041 or 18.313 or 18.440
G (1)
3-0-9

Graduate-level introduction to communication systems and to their implementation with fiber optics technology. Description of signals and noise in the frequency domain. Analog and digital methods of modulation, demodulation, multiplexing, and transmission. Signal-to-noise ratios and error probabilities as measures of system performance. Meets with 6.074, but involves additional discussion, reading, homework, and a design project, all pertaining to fiber optic technology.
R. S. Kennedy

6.451 Principles of Communication (A)

Prereq.: 6.003, 6.432
G (2)
3-0-9

Fundamental principles underlying the transmission of digital data over noisy channels. Mathematical description of signals, noise, and channels. Digital modulation and signal design. Decision regions and optimum receivers. Intersymbol interference and adaptive equalization. Convolutional codes. Fading and multipath channels. Topics of current interest.
P. A. Humblet

6.453 Optical Detection and Communication (A)

Prereq.: 6.041, 6.014
G (2) **Next offered 1989-90**
3-0-9

Basic graduate subject in optical detection and its applications. Phenomenological description of photodetectors. Shot noise, thermal noise, gain-fluctuation noise statistics. Signal-to-noise ratios of direct detection and heterodyne detection systems. Application of noise analysis to free-space, atmospheric, and fiber optic communications. Application of noise analysis to optical detection for phase-sensing interferometers, photon correlation instruments, and optical radars. Alternate years.
J. H. Shapiro

6.454 Advanced Topics in Optical Communication Research (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1989-90**
3-0-9

Discusses advanced topics and current research activities in optical detection, propagation, and communication. Material presented and detailed prerequisites vary from year to year. Topic for 1988-89: coherent laser radars. Term paper required. Alternate years.
J. H. Shapiro

6.455J Geophysical and Oceanographic Signal Processing I (A)

(Same subject as 13.741J)
Prereq.: 2.02 or 6.003, 6.041, 18.075
G (1) **Not to be offered 1989-90**
3-0-9

See description under subject 13.741J.
A. B. Baggeroer

6.456J Geophysical and Oceanographic Signal Processing II (A)

(Same subject as 12.534J, 13.742J)
Prereq.: 6.341 or 12.761 or 13.741J or 12.713
G (2) **Not to be offered 1989-90**
3-1-8

See description under subject 13.742J.
A. B. Baggeroer

Bioelectrical Engineering

6.501 Sound, Speech, Hearing

Prereq.: 6.003
U (1) **Next offered 1989-90**
3-0-9

Introduces the physical, physiological, and psychological bases of auditory communication. Physical acoustics, properties of neural and muscular elements, the vocal tract and speech generation, signal transmission in the auditory system, perception of attributes of speech and speechlike sounds, and the linguistic units that underlie speech events. Disorders of human communication.
K. N. Stevens, L. D. Braida

6.523J Computers and Patient Care

(Same subject as HST 550J)
Prereq.: —
G (2) [P/F]
2-0-4

See description under subject HST 550J.
G. O. Barnett

6.532J Sensory-Neural Systems (A)

(Same subject as 16.352J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Detailed consideration of a number of sensory-neural systems with respect to anatomy, physiology, and mode of operation. Reading of relevant papers and critical discussion of the methods and results described. Topics selected on the basis of their current research interest, with emphasis on systems in which physical input and sensory cell/neuron output can be quantitatively related. Examples from vertebrate species including mechanical, auditory, visual, and other modalities. Alternate years.
L. R. Young, C. M. Oman

6.541J Speech Communication (A)

(Same subject as 24.968J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

Survey of structural properties of natural languages, with special emphasis on the sound pattern. Physiology of speech production, articulatory phonetics. Acoustical theory of speech production; acoustical and articulatory descriptions of phonetic features. Perception of speech: the auditory capabilities of humans; evidence for perceptual correlates of phonetic categories. Mechanical recognition and generation of speech. Recommended prerequisite: mathematical background equivalent to 6.003. Alternate years.
K. N. Stevens, S. J. Keyser

6.542J Laboratory on the Physiology, Acoustics, and Perception of Speech (A)

(Same subject as 24.966J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
2-2-8

Experimental investigations of speech processes. Topics: a) interpretation of x-ray motion pictures, b) measurements of pressure and volume velocity, c) computer-aided waveform analysis and spectral analysis of speech, d) synthesis of speech, e) identification and discrimination of speech-like sounds, and other topics. Recommended prerequisites: 6.501, 6.002 or 18.03. Alternate years.
D. H. Klatt

6.551 Signal Processing by the Auditory System: Physiology (A)

Prereq.: 6.003, 6.023J
G (2) **Not to be offered 1989-90**
3-0-9

Physiological mechanisms involved in signal transmission and processing in the normal and pathological auditory system. Emphasizes the normal ear and brain stem, with some discussion of higher brain levels; current prosthetic approaches. Background other than listed prerequisites may be accepted. Alternate years.
W. T. Peake, T. F. Weiss, N. Y-S. Kiang

6.552 Signal Processing by the Auditory System: Perception (A)

Prereq.: 6.003, 6.041 or 6.431
G (1) **Not to be offered 1989-90**
3-0-9

Studies behavioral aspects of human hearing in relation to current physiological knowledge. Examines performance in processing information from acoustic stimuli. Correlations between behavior and physiology, reflecting the tono-topic organization and stochastic responses of the auditory system. Mathematical models of psychophysical relations, incorporating quantitative knowledge of physiological transformations by the peripheral auditory system. Discusses related research on diagnosis and aids for partially deaf. Alternate years.
L. D. Braida

6.555J Biomedical Signal Processing (A)

(Same subject as 16.356J, HST 582J)
Prereq.: 6.003
G (2)
3-6-3

See description under HST 582J.
W. M. Siebert, B. Delgutte, P. Albrecht

6.561J Fields, Forces, and Flows: Background for Physiology (A)

(Same subject as HST 544J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Conduction, diffusion, convection in electrolytes; fields in heterogeneous media; electrical double layers; Maxwell stress tensor and electrical forces in physiological systems. Fluid and solid continua: equations of motion useful for porous, hydrated biological tissues. Case studies: membrane transport; electrode interfaces; electrical, mechanical, and chemical transduction in tissues; electrophoretic, electroosmotic flows; diffusion/reaction; ECG. Electromechanical and physicochemical interactions in biomaterials and cells; orthopaedic and other clinical examples.
A. J. Grodzinsky

6.562J Ultrasound: Physics, Biophysics, and Technology (A)

(Same subject as 2.76J, HST 530J)
Prereq.: Permission of Instructor
G (1) **Not to be offered 1989-90**
4-1-7

See description under subject 2.76J.
F. R. Morgenthaler, P. P. Lele

6.566J Biomedical Measurements (A)

(Same subject as HST 585J)
Prereq.: Permission of Instructor
G (1)
3-3-6

See description under subject HST 585J.
J. C. Weaver

Electrodynamics

6.601 Fields, Forces, and Motion

Prereq.: 6.013
U (1)
3-0-9

Electromechanical interactions in lumped-parameter and continuum systems. Integral and differential electromagnetic laws, including motion. Lumped electrical and mechanical elements: thermodynamics of discrete electromechanical coupling, equations of motion. Synchronous and induction rotating machines. Linear and nonlinear transducers, transient and steady-state dynamics; electromechanical time constants. Field transformations, dc rotating machines, magnetic diffusion and charge relaxation in moving conductors. Electromagnetic force densities and stress tensors.
J. H. Lang

6.611 Optical Sources, Detectors, and Systems (Revised Content)

Prereq.: 6.003, 6.012
U (2)
3-0-9

Solar and thermal radiation, photons, and Planck's law. Spontaneous and stimulated emission. Laser action. Coherence. Semiconductor lasers. Ideal photon detector. Semiconductor photodiode. Shot noise, Johnson noise. Amplifier noise in FET's. Signal-to-noise ratio and effects on optical system performance. Measurement precision. Detection probabilities. Bit error rates.
R. H. Kingston

6.631 Optics and Optical Electronics (A)

Prereq.: 6.014 or 8.07
G (1)
3-0-9

A first-year graduate subject on fundamental concepts and techniques of modern optics and quantum electronics. Review of Maxwell's equations and the vector properties of light. Interference and interferometers. Temporal and spatial coherence. Scalar diffraction theory. Propagation of spherical and Gaussian-spherical beams. Thin film and "fiber" waveguides. Device applications of electrooptic effect and nonlinear optics.
H. A. Haus, S. Ezekiel

6.632 Electromagnetic Wave Theory (A)

Prereq.: 6.014 or 8.03
G (1)
3-0-9

A first-year graduate subject on electromagnetic field theory, emphasizing mathematical approaches, problem solving, and physical interpretation. Examples deal with propagation, guidance, resonance, radiation, and scattering of electromagnetic waves.
J. A. Kong

6.633 Electrodynamics of Waves, Media, and Interactions(A)

Prereq.: 6.014, 18.04, 18.075
G (2) **Not to be offered 1989-90**
3-0-9

Wave propagation in media with temporal and spatial dispersion; pulse propagation and Green's function analysis. Linear stability theory; absolute and convective instabilities. Energy, momentum, and their flows associated with small-amplitude wave propagation in passive and active media. Geometric optics and mode conversion in inhomogeneous media. Linear and nonlinear coupling of modes in stable and unstable systems. Nonlinear dynamics of order and chaos; solitons and intrinsic stochasticity. Alternate years.
A. Bers

6.634 Nonlinear Optics (A)

Prereq.: 6.014, 8.07
G (2) **Not to be offered 1989-90**
3-0-9

Nonlinear optical phenomena, emphasizing applications, techniques, and devices. Nonlinear polarization: harmonic generation, frequency conversion, optical Kerr effect, self-phase modulation, wavefront conjugation. Pulse propagation in nonlinear media. Applications to fiber optics. Nonlinear laser spectroscopy. Picosecond and femtosecond measurement techniques.
E. P. Ippen, J. G. Fujimoto

6.635 Topics in Electrodynamics (A)

Prereq.: 6.014 or 6.632 or 8.07
G (2)
3-0-9

Material covered differs from year to year according to interest of students and instructor in charge. Typical topics include electrodynamics of moving media, waves in dispersive media, quantum optics, remote sensing, radiative transfer theory and random media. Offered when there are suitable topics with enough student and staff interest.
J. A. Kong

6.637 Optical Information Processing (A)

Prereq.: 6.003, 6.014
G (2)
3-0-9

Systems, algorithms, devices, and applications for optical information processing. Topics: coherent and incoherent optical processors; space-and-time-integrating correlators; space-variant processors; white-light processors; digital optical processors; matrix-algebra processors: symbolic optical processors; optical neural networks; adaptive optics; acoustooptic, electrooptic, and photorefractive spatial light modulators; limitations of optical computers.
C. Warde

6.638 Electrical and Optical Processes in Gases (A)

Prereq.: 8.03, 8.211
G (2) **Next offered 1989-90**
3-0-9

Basic processes in plasmas, lasers, and electrical insulation. Collisions involving particles and radiation fields, including classical and quantum effects. Collective particle behavior, mobility, diffusion, and distribution functions with Max-Boltzmann, Druyvesteyn, and Fokker-Planck approximations. Analysis of surface effects, charge multiplication, breakdown, excitation and inversion mechanisms, and plasma properties. Applications in diagnostics, lasers, plasma etching and processing, switches, dielectrics, and ion sources. Alternate years.
C. M. Cooke

6.641 Microwave Circuits (A)

Prereq.: 6.014
G (2) **Next offered 1989-90**
3-0-9

Electromagnetic wave propagation on uniform and periodic structures, waveguide, stripline, and microstrip. Equivalent circuit representations for apertures and obstacles. Multiport junctions. Non-reciprocal ferrite devices. Cavity resonators. Filters. Perturbation theory. Traveling wave tubes, backward wave oscillators, and free electron lasers. Alternate years.
H. A. Haus

6.642 Antennas and Radiation (A)

Prereq.: 6.014
G (2) **Not to be offered 1989-90**
3-0-9

General theory of radiation and its application to the analysis of representative types of antennas; emphasizes the design of antenna arrays, microwave reflectors, and lenses. Alternate years.
J. A. Kong, F. R. Morgenthaler

6.651J Introduction to Plasma Physics I (A)

(Same subject as 8.613J, 22.611J)
Prereq.: 6.014 or 8.07, 6.018 or 8.044, 18.04 or *18.075*
G (1)
3-0-9

See description under subject 8.613J.
A. Bers, M. Porkolab

6.652J Introduction to Plasma Physics II (A)

(Same subject as 8.614J, 22.612J)
Prereq.: 6.651J or 8.613J or 22.611J, *18.076*
G (2)
3-0-9

See description under subject 22.612J.
A. Bers, R. C. Davidson, K. Molvig

6.653J MHD Theory of Magnetic Fusion Systems I (A)

(Same subject as 22.615J)
Prereq.: 6.651J or 22.601 or 22.611J or 8.613J
G (1)
3-0-9

See description under subject 22.615J.
R. Parker

6.661 Receivers, Antennas, and Signals (A)

Prereq.: 6.014
G (2) **Not to be offered 1989-90**
3-0-9

Detection and measurement of radio and optical signals encountered in communications, astronomy, and radar. Statistical analysis of signal processing systems, including radiometers, spectrometers, interferometers, and digital correlation systems. Matched filters and ambiguity functions. Communications channel performance. Measurement of random electromagnetic fields. Angular filtering properties of antennas, interferometers, and aperture synthesis systems. Radiative transfer and parameter estimation. Alternate years.
D. H. Staelin

6.662J Radar Astronomy, Astrometry, and Geodesy (A)

(Same subject as 12.620J, 8.931J)
Prereq.: 6.014 or 8.03, 18.075 or 18.085
G (1) **Next offered 1989-90**
3-0-9

See description under subject 12.620J.
D. H. Staelin, G. H. Pettengill, C. C. Counselman

6.671 Continuum Electromechanics I (A)

Prereq.: 6.013, 6.601 or 2.03J
G (2)
3-0-9

Quasistatic field dynamics. Transfer relations as an approach to field descriptions. Electromagnetic forces, force densities, and stress tensors, including magnetization and polarization. Classification of energy-conversion processes. Charge migration and relaxation, and magnetic diffusion and induction interactions with material motion. Introduction to electromechanics of continua. Temporal and spatial modes. Spectral numerical techniques. Method of characteristics. Varied applications.
J. R. Melcher

6.672 Continuum Electromechanics II (A)

Prereq.: 6.671
G (1) **Next offered 1989-90**
3-0-9

Laws, approximations, and relations of continuum mechanics. Mechanical and electromechanical transfer relations. Statics and dynamics of electromechanical systems having a static equilibrium. Electromechanical flows. Field coupling with thermal and molecular diffusion. Electrokinetics. Streaming interactions. Applications to materials processing, magnetohydrodynamic and electrohydrodynamic pumps and generators, physiochemical systems, heat transfer, continuum feedback control, electron beam devices, and plasma dynamics. Emphasis on microfabricated systems. Alternate years.
J. R. Melcher

6.683 Operation and Planning of Electric Power Systems (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

Electric power system generation, transmission distribution at a regional (e.g., New England) level. Customer interaction and feedback. Integration of diverse physical, economic, and social phenomena covering time frames ranging from seconds to years. Methods of control, analysis, design, and decision making for such large-scale systems. Special consideration of small distributed generation, rates, load management, and deregulation. Impact of microprocessors. Alternate years.
Staff

6.685 Electric Machines (A)

Prereq.: 6.061 or 6.601
G (2) **Not to be offered 1989-90**
3-0-9

Treatment of transformers, electromechanical transducers, rotating and linear electric machines. Lumped-parameter electromechanics of interaction. Consideration of the basic machine types: dc, induction, synchronous. Development of device characteristics: energy conversion density, efficiency; and of system interaction characteristics: regulation, stability, controllability, and response. Problems taken from current research. Alternate years.
J. L. Kirtley, Jr.

Solid-State Materials and Devices

6.701J Microelectronics Processing Technology

(Same subject as 3.155J, 10.611J)
Prereq.: 6.012
U (1, 2)
3-4-5

Introduces the theory and technology of integrated-circuit fabrication. Lectures and laboratory sessions on basic processing techniques such as diffusion, oxidation, epitaxy, photolithography, chemical vapor deposition, and plasma etching. Emphasis on the interrelationships between material properties, device structure, and the electrical behavior of devices. Provides background for thesis work in microelectronics or for 6.151.
C. G. Sodini, D. A. Rudman, C. V. Thompson, H. H. Sawin

6.720 Semiconductor Devices

Prereq.: 6.012
U (1)
4-0-8

The physics of semiconductor device operation, with emphasis on its application to integrated circuits; introduces use of energy band viewpoint. Topics: theory of p-n junction operation; principles of bipolar transistor operation, including careful development of the Gummel-Poon model; metal-semiconductor junctions; the MOS capacitor; charge-coupled devices and the MOS transistor. First- and second-order effects are discussed for both bipolar and MOS transistors.
J. A. del Alamo

6.730 Physics for Solid-State Applications (A)

Prereq.: 6.013
G (1)
4-0-8

Fundamental physics for solid-state applications, including a review of quantum mechanics and statistical physics: classical and quantum models of electrons in solids; crystal lattices; energy band structures in the nearly free electron and tight binding approximations; effective masses and semiclassical equations of motion; lattice vibrations and phonons; band structures and properties of selected semiconductors. Recommended for first-year graduate students interested in solid-state physics and devices.
T. P. Orlando

6.732 Physics of Solids (A)

Prereq.: 6.730 or 8.231
G (2)
4-0-8

Continuation of material in 6.730. Basic concepts of the quantum theory of solids, emphasizing simple physical models. Topics: electronic structures, dynamics of electrons in solids, Fermi surfaces, transport phenomena in metals and semiconductors; optical properties of metals, semiconductors and insulators; lattice modes; magnetic phenomena in solids, paramagnetism, diamagnetism, ferromagnetism; resonance studies in a magnetic field; superconductivity.
M. S. Dresselhaus

6.734J Application of Group Theory to the Physics of Solids (A)

(Same subject as 8.510J)
Prereq.: 6.732 or 8.232
G (2) **Next offered 1989-90**
3-0-9

Group theory techniques: mathematical background, representation theory, character tables, basis functions, point groups, space groups, double groups, time reversal symmetry. Applications: crystal field structure, selection rules, directed valence and bonds, molecular vibrations, group of the wave vector with application to energy bands, lattice modes. Alternate years.
M. S. Dresselhaus

6.735J Physics of Semiconductors and Devices (A)

(Same subject as 8.532J)
Prereq.: 6.732 or 8.232
G (1)
3-0-9

See description under subject 8.532J.
M. S. Dresselhaus

6.741J Theory of Solids I (A)

(Same subject as 8.511J)
Prereq.: 6.732 or 8.232
G (1)
3-0-9

See description under subject 8.511J.
J. Joannopoulos

6.742J Theory of Solids II (A)

(Same subject as 8.512J)
Prereq.: 6.741J
G (2)
3-0-9

See description under subject 8.512J.
J. Joannopoulos

6.751 Quantum Electronics (A)

Prereq.: 8.211 or 8.05
G (2)
3-0-9

Basic phenomena of quantum electronics, including development of background quantum mechanics and optical properties of solids. Quantization of electromagnetic field and spontaneous plus stimulated optical transitions between energy levels. Resonant processes, including electric dipole transitions, absorption dispersion, and saturation. The laser and its operating characteristics. Rate equations, optical pumping, Q-switching, and mode locking. Nonlinear optics. Electrooptical devices, picosecond switches and pulse generation, optical logic gates. Fiber optics.
G. W. Pratt, Jr.

6.753 High-Frequency Magnetics and Magnetic Recording (A)

Prereq.: 6.014 or 6.601
G (2) **Next offered 1989-90**
3-0-9

Basic principles underlying static and dynamic behavior of magnetic materials used for high-frequency application and information storage. Theory of magnetic domains, including magnetic bubbles; magnetic resonance; propagation of electromagnetic, magnetostatic, and magnetoelastic waves. Linear and nonlinear microwave ferrite devices. Introduction to longitudinal and transverse magnetic recording. Alternate years.
F. R. Morgenthaler

6.762 Dielectric and Optical Materials and Devices (A)

Prereq.: 6.013
G (1) **Next offered 1989-90**
3-0-9

Devices dependent on polarization rather than transport. Tensor properties and crystal symmetry. Nonlinear dielectrics: ferroelectrics, parametric amplification. Elasticity. Coupled effects: pyro- and piezo-electricity. Optical properties: waves in anisotropic crystals; indicatrix; electrooptics, photoelasticity, optical modulators; beam deflectors. Nonlinear optics: frequency doubling; parametric conversion; photorefractive effects. Alternate years.
D. J. Epstein

6.763 Applied Superconductivity (A)

Prereq.: 6.013 or 8.07
G (2) **Next offered 1989-90**
3-0-9

Phenomenological approach to superconductivity, surveying large-scale and small-scale applications. Electrodynamics of superconductors, London's model, flux quantization. Type II superconductors, upper critical fields, pinning, critical state model Josephson Junctions and superconducting quantum devices, equivalent circuits and analogs, computers. Brief overview of superconducting materials and microscopic theory. Some background in solid-state physics helpful. Alternate years.
T. P. Orlando

6.771 Physics of Semiconductor Devices (A)

Prereq.: 6.730, 6.012
G (2)
3-0-9

The physical basis of semiconductor device operation. Homogeneous and inhomogeneous semiconductors in equilibrium; electrochemical potential; generation-recombination mechanisms; Boltzmann transport equation; ambipolar transport, p-n homojunctions and heterojunctions; Schottky diodes, MOS capacitors; Gummel approach to bipolar devices; Zener and avalanche breakdown; high-level injection; quasi-static behavior of bipolar and MOS transistor; pnpn devices; CMOS; latchup.
S. D. Senturia

6.772 Integrated Circuit Devices and Processes (A)

Prereq.: 6.720
G (1)
3-0-9

Silicon integrated circuit technology. Theory and practice of IC fabrication and device design, emphasizing their relation to circuit performance. Topics: materials and fabrication processes; large-signal models for bipolar and field-effect transistors; components and circuit building blocks for modern digital ICs; circuit layout considerations in LSI; computer-aided analysis and design of processes, devices, and circuits, using state-of-the-art simulators.
D. A. Antoniadis

6.773 Topics in Semiconductor Device Research (A)

Prereq.: 6.720, 6.018; or 6.771
G (2) **Next offered 1989-90**
3-0-9

Topics selected from current device research areas. In recent years, subject matter has included Schottky barriers and heterojunctions, charge-coupled devices, diode lasers, quantum well devices, and ultrahigh-speed transistors, including the heterojunction bipolar, high electron mobility, and permeable base transistors. Emphasis on device physics as it relates to device performance. Alternate years.
A. L. McWhorter, C. G. Fonstad, Jr.

6.774 Physics of Microelectronic Fabrication (A)

Prereq.: 6.701J
G (1)
3-0-9

Fundamental principles of the processes used in the fabrication of silicon monolithic integrated circuits. Physical models of bulk crystal growth, thermal oxidation, solid-state diffusion, ion implantation, epitaxial deposition, chemical vapor deposition, and thin-film deposition. Refractory metal silicides, plasma and reactive ion etching, rapid thermal processing. Technological limitations on integrated circuit design and fabrication. VLSI fundamentals.
L. R. Reif

6.775 Design of Analog MOS LSI (A)

Prereq.: 6.301
G (2)
3-0-9

A detailed exposition of the principles involved in designing analog circuits in MOS LSI. Device physics, small signal and large signal models. Biasing. Basic circuit building blocks. Operational amplifier design. Large signal considerations. Principles of switched capacitor networks. Applications: fully integrated filters, comparators, A/D and D/A converters, PCM encoders and decoders; other signal processing circuits. A comprehensive design project is a required part of the subject.
H. S. Lee, C. G. Sodini

6.776J Plasma Processing in Integrated Circuit Fabrication (A)

(Same subject as 10.616J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

Studies glow discharge properties and processes as applied to integrated circuit fabrication. The physics and chemistry of nonequilibrium plasmas. Emphasizes the plasma kinetics and plasma-surface interactions. Extensively reviews plasma etching processes, sputter deposition, and plasma enhanced chemical vapor deposition for the fabrication of VLSI devices. Alternate years.
L. R. Reif, H. H. Sawin

6.781 Submicrometer Structures Technology (A)

Prereq.: —
G (2)
3-0-9

Surveys techniques to fabricate and analyze submicrometer structures, with applications. Reviews optical and electron microscopy. Surface characterization, preparation, and measurement techniques. Resist technology. Optical projection, holographic, X-ray, ion, and electron lithography. Aqueous, ion, and plasma etching techniques. Lift-off, film growth, and electroplating. Ion implantation. Applications in microelectronic devices, optical devices, and X-ray optics. Undergraduates with permission of instructor.
H. I. Smith

6.791 Special Topics in the Solid State and Its Application (A)

Prereq.: —
G (1)
3-0-9

6.792 Special Topics in the Solid State and Its Application (A)

Prereq.: —
G (2)
3-0-9

Primarily for those interested in research on solid-state materials and devices for electrical and electronic applications. Topics and staff to be announced each term. Given independently or sequentially as circumstances require. Permission of instructor required.
D. J. Epstein

Computer Science

6.801 Machine Vision

Prereq.: 6.003
U (1)
3-0-9

Deriving a symbolic description of the environment from an image. Understanding physics of image formation. Image analysis as an inversion problem. Binary image processing and filtering of images as preprocessing steps. Recovering shape, lightness, orientation, and motion. Using constraints to reduce the ambiguity. Photometric stereo and extended Gaussian sphere. Applications to robotics; intelligent interaction of machines with their environment.
B. K. P. Horn

6.802 Robot Manipulation

Prereq.: 8.01, 18.02
U (2)
3-0-9

Introduces kinematic, dynamic, and spatial constraints on robot motion. Basic considerations in design and application of robot systems. Solving kinematics of robot manipulators. Planning trajectories subject to position, velocity, and acceleration constraints. Using rigid-body dynamics in the control of robots. Controlling force and compliance in manipulation. Survey of basic issues in robot programming. Development of algorithms for automatic synthesis of robot programs. Programming experience recommended.
T. Lozano-Perez

6.821 Programming Languages (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Principles of functional, imperative, and logic programming languages. Meta-circular interpreters, semantics (operational, denotational, and axiomatic), type systems (polymorphism, inference, and abstract types), object oriented programming, modules, multiprocessing. Case studies of contemporary programming languages. Programming experience and background in language implementation required.
D. K. Gifford

6.823 Computer System Architecture (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Emphasizes the relationships among hardware organization, systems programming, and language support in the evolution of computer architecture. Effect of instruction set design on performance and programmability; methods of addressing, creating, protecting, and storing data and procedure objects; processor and memory design and programming issues in vector and multiprocessor systems. Assumes undergraduate knowledge of programming languages and computer systems.
Arvind

6.824 Artificial Intelligence (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Intensive introduction to central issues of constructing intelligent systems. Historical trends in AI research: generality in problem solving, role of particular knowledge. Formalisms for knowledge representation: predicate logic, semantic networks, "frame" systems, production rules. Problem-solving techniques: goal-directed behavior, natural deduction, resolution, production system architectures, reasoning about control, planning, dependency-directed control, constraints, truth maintenance. Expects working knowledge of LISP.
P. Szolovits, H. E. Shrobe

6.830J Program Semantics and Verification (A)

(Same subject as 18.427J)
Prereq.: 6.821, 6.045J or 6.840J or 6.044J
G (2) **Next offered 1989-90**
3-0-9

Presentation by faculty and students on mathematical approaches to defining semantics of simple programming languages: denotational, operational, and axiomatic semantics. Formal systems for program verification: soundness and completeness. Logics of programs, type theory, lambda calculus. Further topics selected from semantics and verification of complex languages with concurrent and parallel constructs; current verification technology. May be repeated for credit. Alternate years.
A. R. Meyer

6.835 Concurrent Systems for Artificial Intelligence (A)

Prereq.: 6.001, 6.034
G (1)
3-0-9

Concurrent systems and their relationship to artificial intelligence. Organizations as exemplars of highly intelligent parallel systems. Concurrent architectures for artificial intelligence (e.g., Apiary, Connection Machine, and parallel Prolog machines). Incrementally evolving networks of computers. Mathematical models of concurrent systems (e.g., Actor Model, Milner's algebraic model, and Hoare's process model).
C. E. Hewitt

6.840J Theory of Computation (A except XVIII)

(Same subject as 18.404J)
Prereq.: 18.063 or 18.310
G (1)
4-0-8

See description under subject 18.404J.
M. F. Sipser

6.841J Advanced Complexity Theory (A)

(Same subject as 18.405J)
Prereq.: 6.840J
G (2)
3-0-9

See description under subject 18.405J.
S. Goldwasser, M. F. Sipser

6.845 Concurrent VLSI Architecture (A) (New)

Prereq.: 6.823, 6.371
G (2) **Not to be offered 1989-90**
3-5-4

Principles and practical issues in the construction of VLSI computing systems. Methods to estimate cost and performance. Trends in VLSI technology. Special purpose VLSI chips: logic added memories, intelligent sensors, signal and image processors. Communication in VLSI systems: power, density, and timing models; network topology; routing algorithms; performance analysis. Concurrent computers: programming, addressing, synchronization, data movement, control flow. Class project. Alternate years.
W. J. Dally

6.847 Dataflow Architecture and Languages (A)

Prereq.: 6.001, 6.004
G (1)
3-0-9

Dataflow model as a basis for designing parallel systems. Suitability of functional languages for programming parallel machines; data- and demand-driven execution models; dataflow program graphs; static and dynamic dataflow machines; compiling into dataflow graphs; lambda calculus and combinators; term rewriting systems; polymorphic types; reduction machines; nondeterministic programming and resource managers.
Arvind

6.848J Theory of Parallel and VLSI Computation (A)

(Same subject as 18.435J)
Prereq.: 6.046J or 6.851J
G (1)
3-0-9

See description under subject 18.435J.
C. E. Leiserson, F. T. Leighton

6.849J Advanced Parallel and VLSI Computation (A)

(Same subject as 18.436J)
Prereq.: 6.848J
G (2) **Not to be offered 1989-90**
3-0-9

See description under subject 18.436J
C. E. Leiserson, F. T. Leighton

6.851J Theory of Algorithms (A except XVIII)

(Same subject as 18.414J)
Prereq.: 18.06 or 18.710, 18.063 or 18.310
G (2)
3-0-9

See description under subject 18.414J.
R. L. Rivest

6.852J Distributed Algorithms (A)

(Same subject as 18.437J)
Prereq.: —
G (1) **Not to be offered 1989-90**
3-0-9

Design and analysis of concurrent algorithms, emphasizing those suitable for use in distributed networks. Process synchronization, allocation of computational resources, distributed consensus, distributed graph algorithms, election of a leader in a network, distributed selection, distributed termination, deadlock detection, concurrency control, communication, clock synchronization. Special consideration given to issues of efficiency and fault tolerance. Formal models for distributed computation. Alternate years.
N. A. Lynch

6.853 Computer Systems (A)

Prereq.: 6.033
G (2) **Next offered 1989-90**
3-0-9

Study and discussion of the literature of computer systems. Subject is designed to help students understand the nature of research in computer systems and to develop a student's ability to judge ideas critically. Computer architecture, networks, operating systems, programming language/system interface, network protocols, file systems, replication, protection, transactions, database systems, computer graphics, user interfaces, and application systems. Alternate years.
D. K. Gifford

6.854J Advanced Algorithms (A)

(Same subject as 18.415J)
Prereq.: 6.851J, 18.06 or 18.710
G (1)
3-0-9

See description under subject 18.415J.
R. L. Rivest, E. Tardos

6.858J Machine Learning (A) (New)

(Same subject as 18.428J)
Prereq.: 6.034, 6.041 or 6.045 or equivalents
G (1)
3-0-9

Formal models of machine learning; learning concepts from examples; learnable classes of concepts; boolean formulae; geometric concepts; representing prior knowledge; computational limitations; pattern recognition; Bayesian learning; connectionist models; perceptrons, back-propagation; distribution-free learning; validating what's learned; coping with noise; identifying finite automata and Markov chains, speech recognition applications; identification of programs in the limit; extrapolation; learning from positive data only.
R. L. Rivest

6.863 Natural Language and the Computer Representation of Knowledge (A)

Prereq.: 6.034
G (2)
3-0-9

Relationship between computer representation of knowledge and the structure of natural language. Emphasizes development of the analytical skills necessary to judge the computational implications of grammatical formalisms, and uses concrete examples to illustrate particular computational issues. Efficient parsing algorithms for context-free grammars; augmented transition network grammars. Question answering systems; computer acquisition of syntactic knowledge. Models for the semantics of English relevant to symbolic computation.
R. C. Berwick

6.865J Legged Locomotion in Robots and Animals (A)

(Same subject as 9.374J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Intensive introduction to the principles of legged locomotion, as they apply to walking robots and to biological systems. Topics: selection and coordination of gait, energetics and speed, mechanical design, control of balance, algorithms for rough terrain, and gymnastics. Testing of published models and algorithms through computer simulations.
M. H. Raibert

6.866 Machine Vision (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Intensive introduction to the process of generating a symbolic description of the environment from an image. Students expected to attend the 6.801 lectures as well as occasional seminar meetings on special topics. Material presented in 6.801 is supplemented by reading from the literature. Students required to prepare a paper analyzing research in a selected area.
B. K. P. Horn

6.867 Robot Manipulation (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Intensive introduction to the planning and control of robot motion. Students expected to attend the 6.802 lectures as well as occasional seminar meetings on special topics. Material presented in 6.802 is supplemented by reading from the literature. Students required to prepare a paper analyzing research in a selected area.
T. Lozano-Perez

6.868 The Society of Mind (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Introduction to a theory that tries to explain how minds are made from collections of simpler processes. Treats such aspects of thinking as vision, language, learning, reasoning, memory, consciousness, ideals, emotions, and personality. Incorporates ideas from psychology, artificial intelligence, and computer science to resolve theoretical issues such as wholes vs parts, structural vs functional descriptions, declarative vs procedural representations, symbolic vs connectionist models, and logical vs common-sense theories of learning.
M. L. Minsky

6.871 Knowledge-Based Applications Systems (A)

Prereq.: 6.034, 6.036 or 6.824
G (2)
3-0-9

Development of programs containing a significant amount of knowledge about their application domain. Outline: 1) brief review of relevant AI techniques; 2) case studies from a number of application domains, chosen to illustrate principles of system development; 3) discussion of technical issues encountered in building a system, including selection of knowledge representation, knowledge acquisition, etc.; and 4) discussion of current and future research. Hands-on experience in building an expert system (term project).
R. S. Patil

6.875J Cryptography and Cryptanalysis (A)

(Same subject as 18.425J)
Prereq.: 6.046J or 6.851J or 6.047J
G (2)
3-0-9

Computational complexity-based cryptography. One-way and trapdoor functions. Public-key cryptosystems. Digital signature schemes. Probabilistic encryption. Computational complexity measures of knowledge and protocols for secure transactions: coin flipping by telephone, oblivious transfer. Multi-party protocols. Perfect pseudorandom number generation and construction of pseudorandom functions.
S. Goldwasser

6.876J Advanced Topics in Cryptography (A)

(Same subject as 18.426J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Recent results in public-key cryptography, pseudorandom number generation, protocols for secure transactions, and cryptanalysis presented and discussed. A series of lectures on isolated topics by instructor and invited speakers. May be repeated for credit.
S. Micali

6.891-6.899 Special Topics in the Computer Sciences (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

A seminar-type discussion of special topics in the computer sciences. Opportunity for graduate students and instructors to investigate a topic of common interest. Topic and staff announced each term. These subjects given independently or sequentially, as circumstances require.
F. J. Corbató

Special Subjects

6.901 Inventions and Patents

Prereq.: 14.02
U (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. H. Rines

6.903J Automation, Robotics, and Unemployment (New — Context Subject)

(Same subject as STS 013J)
Prereq.: —
U (1)
3-0-9

Exploration of the short- and long-term effects of increased automation and the use of robots and computers on unemployment levels. Various aspects of the issue are examined through lectures, readings, and library research in a combined lecture and seminar mode. Term paper required. Latter half of semester is devoted to oral progress reports and group discussion of the papers. May *not* count toward HASS Requirement.
L. D. Smullin, M. R. Smith

6.910 Special Studies in Electrical Engineering and Computer Science

Prereq.: —
U (1, 2, S)
Arr.

Opportunity for individual study at the undergraduate level related to electrical engineering and computer science not covered by other subjects offered by the Department. Student is responsible for initiation of arrangements and filing of proposal. Consult Department Undergraduate Office.
L. A. Gould

6.911-6.919 Special Subjects in Electrical Engineering and Computer Science

Prereq.: —
U (1, 2)
Arr.

Opportunity for group study of undergraduate subjects related to electrical engineering and computer science not otherwise included in curriculum. Programs subject to approval of professor in charge.
L. A. Gould

6.921 VI-A Internship

Prereq.: —
U (S) [P/F]
0-12-0

Provides academic credit for the first two Assignments of VI-A students at companies affiliated with the Department's VI-A Internship Program. Students register for this subject twice. The grade of "J" is given following completion of the first Assignment. Students must complete the second Assignment in order to receive the full academic credit of 24 units for this subject. Enrollment limited to students participating in the VI-A Internship Program.
K. J. O'Toole

6.922 Advanced VI-A Internship

Prereq.: 6.921
U (2, S) [P/F]
0-12-0

Provides academic credit for the third Assignment of VI-A students at companies affiliated with the Department's VI-A Internship Program. Enrollment limited to students participating in the VI-A Internship Program.
K. J. O'Toole

6.925 Engineering Internship

Prereq.: —
U (1, 2, S) [P/F]
0-6-0

Provides academic credit for the first two Work Assignments of Electrical Engineering and Computer Science students participating in the Engineering Internship Program. Students register for the subject twice. The grade of "J" is given following completion of the first Work Assignment. Students must complete the second Work Assignment in order to receive the full academic credit of 12 units for this subject. Enrollment limited to Course VI students participating in the Engineering Internship Program.
J. K. Roberge

6.929 Undergraduate Thesis Presentation

Prereq.: —
U (1, 2, S)
0-3-0

Registration for written and oral presentation of the undergraduate thesis, when the thesis work is an extension of a project laboratory or is carried out as part of a VI-A Assignment. Consult Department Undergraduate Office.
L. A. Gould

6.930 Management in Engineering

Prereq.: —
U (1)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult

6.931 Development of Inventions and Creative Ideas (A)

Prereq.: 14.002
G (2)
3-0-9

Role of the engineer as patent expert and as technical witness in court and patent interference and related proceedings. Rights and obligations of engineers in connection with educational institutions, government, and large and small businesses. Various manners of transplanting inventions into business operations, including development of New England electronics industry and its different types of institutions. American systems of incentive to creativity apart from the patent laws in the atomic energy and space fields. For graduate students only; others see 6.901.
R. H. Rines

6.932 Nuclear Weapons and Arms Control: Technology and Policy Issues

Prereq.: —
G (1)
4-0-8

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
G. W. Rathjens, J. P. Ruina

6.934 Nuclear War: Threat and Avoidance

Prereq.: —
U (2) HASS
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, E. G. Rothschild, J. P. Ruina

6.936 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult

6.938 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

6.939 Probabilistic Models in Engineering (Revised Content)

Prereq.: 1.03 or 6.041 or 18.05
U (2)
3-2-7

New School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. R. Odoni, R. C. Larson, H. N. Psaraftis

6.940 Optimal Design of Engineering Systems (Revised Content)

Prereq.: 1.00 or equivalent
U (1)
3-1-8

New School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. C. Larson, H. N. Psaraftis, Y. Sheffi

6.942J Cases and Issues in Engineering Management (A)

(Same subject as 15.368J)
Prereq.: —
G (2)
3-0-6

Case studies of engineering and business management in industry and government illustrate strategic planning, product strategy, R&D planning, technology assessment, technology transfer, and project management. Discussion of current issues in advanced technologies: technology life cycle and its implications for technology forecasting and strategic planning; quality control systems for innovation management; impact of computer integrated manufacturing on industrial trade and joint ventures between East and West.
T. H. Lee

6.951 Graduate VI-A Internship

Prereq.: 6.922
G (1, S) [P/F]
0-12-0

Provides academic credit for a Graduate Assignment of graduate students at companies affiliated with the Department's VI-A Internship Program. Enrollment limited to graduate students participating in the VI-A Internship Program.
K. J. O'Toole

6.952 Graduate VI-A Internship

Prereq.: 6.951
G (1, 2, S) [P/F]
0-12-0

Provides academic credit for graduate students who require an additional term at the company to complete the Graduate Assignment of the Department's VI-A Internship Program. This academic credit is for registration purposes only and cannot be used toward fulfilling the requirements of any degree program. Enrollment limited to graduate students participating in the VI-A Internship Program.
K. J. O'Toole

6.955 Advanced Engineering Internship

Prereq.: 6.925
G (1, 2, S) [P/F]
0-6-0

Provides academic credit for the third Work Assignment of Electrical Engineering and Computer Science graduate students participating in the Engineering Internship Program. Students register for the subject twice. The grade of "J" is given following completion of the first term of the Work Assignment. Students must complete the second term of the Work Assignment in order to receive the full academic credit of 12 units for this subject. Enrollment limited to Course VI graduate students participating in the Engineering Internship Program.
J. K. Roberge

6.961 Introduction to Research in Electrical Engineering and Computer Science

Prereq.: —
G (1, 2)
Arr.

Opportunity to become involved in graduate research, under guidance of a staff member, on a problem of mutual interest to student and supervisor. Recommended for all entering full-time graduate students in the Department of Electrical Engineering and Computer Science. Individual programs subject to approval of professor in charge. Enrollment restricted to regular graduate students in Electrical Engineering and Computer Science. Normal registration is for 12 units.
D. J. Epstein

6.962-6.969 Special Studies in Electrical Engineering and Computer Science

Prereq.: —
G (1, 2)
Arr.

Opportunity for study of graduate-level topics related to electrical engineering and computer science but not included elsewhere in the curriculum. Registration under this subject normally used for situations involving individual study (under supervision of a faculty member) of topics of mutual interest to student and supervisor, but may, when appropriate, be used for small study groups. Normal registration is for 12 units. Registration subject to approval of professor in charge.
D. J. Epstein

6.971-6.979 Special Subjects in Electrical Engineering and Computer Science (A)

Prereq.: —
G (1, 2)
Arr.

Opportunity for group study of advanced subjects related to electrical engineering and computer science not otherwise included in curriculum. Programs subject to approval of professor in charge.
D. J. Epstein

6.980 Teaching Electrical Engineering and Computer Science

Prereq.: —
G (1, 2) [P/F]
Arr.

For qualified students interested in gaining teaching experience. Classroom, tutorial, or laboratory teaching under the supervision of a faculty member. Enrollment limited by availability of suitable teaching assignments. Students selected by interview.
F. C. Hennie

6.981-6.989 Teaching Electrical Engineering and Computer Science

Prereq.: —
G (1, 2) [P/F]
Arr.

For Teaching Assistants in Electrical Engineering and Computer Science, in cases where teaching assignment is approved for academic credit by the Department.
F. C. Hennie

6.991-6.999 Research in Electrical Engineering and Computer Science

Prereq.: —
G (1, 2, S) [P/F]
Arr.

For Research Assistants in Electrical Engineering and Computer Science, in cases where the assigned research is approved for academic credit by the Department. Hours arranged with research supervisor.
A. C. Smith

6.UR Undergraduate Research in Electrical Engineering and Computer Science

Prereq.: —
U (1, 2, S) [P/F]
Arr.

Extended participation in the work of a faculty member or research group, including independent study of the literature, direct involvement in the group's research, and project work under an individual faculty member. Research is arranged by mutual agreement between the student and a member of the faculty of the Department of Electrical Engineering and Computer Science, and may continue over several terms. Forms and instructions for the initial letter of intent and final summary report are available in the Department Undergraduate Office. Grading P/F only.
R. D. Thornton

6.ThU Undergraduate Thesis

Prereq.: —
U (1, 2, S)
Arr.

Program of undergraduate research leading to the writing of an S.B. thesis; to be arranged by the student and an appropriate MIT faculty member. Students who register for thesis must consult Department Undergraduate Office.
L. A. Gould

6.ThG Graduate Thesis (A)

Prereq.: —
G (1, 2, S)
Arr.

Program of graduate research leading to the writing of an S.M., E.E., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member.
A. C. Smith

Course 7 Biology

7.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in the Department of Biology. For further information, consult the Departmental Coordinator: D. E. Housman. A written report is required. Permission of Department required. Consult Department headquarters.

7.00J AIDS: Scientific Challenge and Human Challenge (New — Context Subject)

(Same subject as 15.60J)
Prereq.: —
U (1)
3-0-3

AIDS presents a challenge for many disciplines. As a public health and policy issue, it is a challenge to our ethical beliefs and to the taxpayer. As a scientific problem, it is a test of our ability to find methods of cure and prevention. As an international issue, it threatens economic and social progress in the developing world. Lectures illuminate AIDS as a challenge in molecular biology, epidemiology, economics, management, public policy, and other professions. Ten lectures: subject ends November 21. Limited enrollment.
D. Baltimore, M. Rowe

7.01 General Biology

Prereq.: —
U (2) SD
4-0-8

Introduction to cell biology, biochemistry, and genetics, stressing molecular and quantitative aspects, to serve as a "language" for discussions of current research in molecular biology. Topics may include membrane cell biology and human disease; DNA biochemistry in bacteria; molecular neurobiology of learning; oncogenes; immunology; sex determination; cell structure and cell behavior; molecular biology of aging.
V. M. Ingram

7.011 Introduction to Experimental Biology

Prereq.: 7.01 or 7.05
U (1, 2) LAB
2-8-5

Application of experimental techniques in biochemistry, microbiology, and cell biology. Emphasizes integrating factual knowledge with understanding the design of experiments and data analysis to prepare the students for research projects.
Term 1: *P. T. Matsudaira, B. H. Cochran*
Term 2: *A. Torriani, D. Page*

7.03 Genetics

Prereq.: —
U (1)
4-0-8

Continuity and variation in the multiplication of living organisms. Mutation and selection as a mechanism for biological change. Principles of formal genetics. Physical and chemical basis of heredity. Structure and function of the hereditary material. Molecular basis for mutation, genetic function, and recombination in microorganisms.
H. R. Horvitz, M. S. Fox

7.031 Experimental Microbial Genetics

Prereq.: 7.011, 7.03, 7.05
U (2) **Next offered 1989-90**
2-16-6

Laboratory project in microbiology and genetics. In 1987-88, used advanced genetic approaches based on the use of transposon and gene and operon fusions to address problems related to the nodulation of alfalfa by the nitrogen-fixing bacterium *Rhizobium meliloti*. Enrollment limited.
G. C. Walker

7.04 Cell and Developmental Biology

Prereq.: 7.08
U (2)
4-0-8

Basic properties of cells and their relationship to development: biochemical and structural differentiation of cells. Principles of embryology and development: determination, pattern formation, and cell-cell interaction. Analysis of development by techniques of cell biology, genetics, molecular biology, and biochemistry.
R. Jaenisch, T. Orr-Weaver, H-S. Shin

7.041 Experimental Drosophila Molecular Genetics (New)

Prereq.: 7.011, 7.03, 7.05
U (2)
2-16-6

Laboratory project applying molecular genetic techniques to selected problems in Drosophila biology. Insertional mutagenesis with P transposable elements used to generate mutations affecting embryonic development and the regulation of gene expression. Mutant phenotypes characterized and the corresponding genes analyzed using standard recombinant DNA techniques. Molecular cloning and Drosophila cell culture methods used to address questions of gene regulation.
D. Rio, H. Steller

7.05 General Biochemistry

Prereq.: 5.12
U (1) SD
5-0-7

Contributions of biochemistry toward an understanding of the structure and functioning of organisms, tissues, and cells. Chemistry and functions of constituents of cells and tissues and the chemical and physical-chemical basis for the structures of nucleic acids, proteins, and carbohydrates. General metabolism of carbohydrates, fats, and nitrogen-containing materials such as amino acids, proteins, and related compounds.
G. M. Brown, U. L. RajBhandary

7.06 Metazoan Cell Biology

Prereq.: 7.01 or 7.05
U (2)
3-0-9

Molecular and structural biology of cells and higher organisms. Macromolecular biochemistry, including RNA synthesis and processing and protein synthesis. Structure, function, and formation of subcellular components and organelles. Structural networks in cells and their relation to tissue. Emphasizes biochemistry and electron microscopic anatomy.
S. Penman

7.08 Cell and Molecular Biology

Prereq.: 7.03, 7.05
U (2)
4-0-8

Nucleic acid molecular biology: mechanisms of DNA replication, regulation of gene expression in prokaryotes and eukaryotes, including the biosynthesis of RNA and proteins. Recombinant DNA technology. Structure, biogenesis, and functions of subcellular organelles and membranes. Cytoskeleton and extracellular matrix. Control of cell growth and oncogenes.
B. J. Meyer, R. A. Weinberg

7.09J Cellular Neurobiology

(Same subject as 9.09J)
Prereq.: 7.05
U (2)
4-0-8

An introduction to the structure and function of the nervous system. Emphasis placed on the cellular properties of neurons and other excitable cells. Includes the structure and biophysical properties of excitable cells, synaptic transmission, neurochemistry, neurodevelopment, and integration of information in simple systems and the visual system.
S. J. Burden, R. D. G. McKay, W. G. Quinn

7.11 Biology Teaching

Prereq.: —
U (1, 2) [P/F]
Arr.

For qualified undergraduate students interested in gaining some experience in teaching. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. Consult Department headquarters.

7.15 Experimental Molecular Biology: Biotechnology I

Prereq.: 7.011, 7.03, 7.05
U (1)
2-16-6

Laboratory project applying recombinant DNA and other modern genetic techniques to problems in prokaryotic genetics. Cloning of genes from a variety of prokaryotic and lower eukaryotic organisms, and characterization of the cloned genes for structure and function.
R. A. Young, P. W. Robbins

7.16 Experimental Molecular Biology: Biotechnology II

Prereq.: 7.011, 7.03, 7.05
U (2)
2-16-6

Laboratory methodology and theoretical basis for cloning and manipulation of genes in eukaryotic organisms. Mammalian cell culture, biological assays with mammalian cells, isolation of hybridomas that secrete monoclonal antibodies, and cloning and expression of genes in eukaryotic organisms.
R. C. Mulligan, D. E. Housman

7.21 Microbial Physiology

Prereq.: 7.05
U (1)
4-0-8

Biochemical properties of bacteria and other microorganisms that enable them to grow under a variety of conditions. Interaction between bacteria and bacteriophages. Genetic and metabolic regulation of enzyme action and enzyme formation.
B. Magasanik, G. C. Walker

7.24 Topics in Bacteriology (A)

Prereq.: 7.21
G (1) [P/F]
2-0-6

Recent developments in bacteriology: regulatory mechanisms and membrane phenomena. Permission of instructor required. Consult Department headquarters.

7.25 Topics in Bacterial Viruses

Prereq.: 7.21, 7.27
G (2)
2-0-6

Biological and molecular properties of bacteriophages as model systems for the study of viruses and as prototypes of noncellular organisms are presented and discussed on the basis of specific examples from current literature. Consult Department headquarters.

7.26 Animal Virology

Prereq.: 7.21
G (1)
3-0-9

General survey of animal virology, including studies of their genome organization, virion structure, genetics; virus interaction with the infected cell and the immune system. The virus is viewed as a model system of the macromolecular metabolism of the cell. The pathogenesis of medically important virus diseases is discussed.
R. A. Weinberg, P. A. Sharp, N. H. Hopkins

7.27 Regulation of Gene Expression (A)

Prereq.: 7.03, 7.05
G (2)
4-0-8

Studies molecular mechanisms responsible for the regulation of gene expression in bacteria, bacterial viruses, and eukaryotic microorganisms.
B. Magasanik, A. Grossman

7.28 Topics in Nucleic Acid Biochemistry (A)

Prereq.: 7.03, 7.05
G (1)
3-0-9

Genome structure and function, with an emphasis on regulation of DNA transactions, protein synthesis, and selective protein turnover in both bacteria and eukaryotes. Each topic is covered by in-depth discussion of specific recent developments in the field.
A. Varshavsky

7.30 Method and Logic in Molecular Biology (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Logic and experimental design: an in-depth discussion and assessment of biochemical, physical, and genetic methods employed in testing hypotheses. Limited to Course VII graduate students.
F. Solomon, M. L. Pardue, H. R. Horvitz, M. L. Gefter

7.31 Biochemistry for Graduate Students (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Fundamental principles of biochemical analysis of the mode of action and structure of regulatory, binding, and catalytic proteins.
R. T. Sauer, F. Solomon

7.32J Analysis of Differentiation and Development

(Same subject as 9.320J)
Prereq.: 7.05 or 7.33
G (2) [P/F]
3-0-9

Graduate discussion seminar examining in-depth fundamental aspects of development and differentiation. In addition, particular attention paid to the critical appraisal of current published research in important areas of the field.
M. L. Pardue, W. G. Quinn

7.33 Genetics for Graduate Students (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Principles of genetics, including Mendelian systems and prokaryotic genetics. Application of principles to biological function, including regulation and development. Mechanisms of recombination, mutation, and evolution. Discussion of original scientific papers and review of problem sets and exams supplement lectures.
G. R. Fink, T. Orr-Weaver

7.38J The Protein Folding Problem

(Same subject as 5.48J)
Prereq.: 7.05 or equivalent
G (2)
3-0-6

Focus on the mechanism by which the amino acid sequence of polypeptide chains determines their 3-dimensional conformation: conformation of linear and cyclic peptides; structure-activity relationships for peptide hormones; hydrophilicity and hydrophobicity scales; helix and sheet packing; unfolding and refolding of proteins in vitro; aggregation reactions; folding of newly synthesized polypeptide chains in vivo; genetic analysis of folding pathways; conformation of active sites; design of new active sites; protein stability.
J. A. King

7.411-7.419 Seminars in Biological Oceanography (A)

Prereq.: —
G (1, 2)
Arr.

Selected topics in biological oceanography. Permission of instructor required. 7.417 and 7.419 are taught P/F. Information: A. L. Peirson (Woods Hole Staff).

7.421 Special Problems in Biological Oceanography (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

Advanced problems in biological oceanography with assigned reading and consultation. Information: A. L. Peirson (Woods Hole Staff).

7.47 Biological Oceanography

Prereq.: —
G (2)
15-6-15

Intensive overview of biological oceanography. After introductions to physical, chemical, and geological oceanography and diversity of life in the oceans, fundamental topics in population dynamics, behavioral and community ecology, population genetics, physiology and biochemistry of marine organisms form the first part. Subsequent one-week sessions include microbiology, phytoplankton, zooplankton, biogeochemistry, sediment dynamics, benthos, and evolution. Laboratory, field work, and discussion in addition to lectures. Undergraduates admitted by permission of instructor only.
(Woods Hole Staff): F. Grassle

7.491 Research in Biological Oceanography (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

Directed research in biological oceanography not leading to graduate thesis and generally done before the qualifying examination. Possible areas include population dynamics, physiology, and cytology of marine microorganisms; physiology, nutrition, and productivity of phytoplankton; influence of organisms on the composition of seawater; systematics, physiology, and ecology of pelagic larvae, zooplankton, benthos, and mesopelagic fishes; physiology and migration of large fishes; diving physiology; and use of sound by marine mammals.
(Woods Hole Staff)

7.52J Biotechnology of Mammalian Cells

(Same subject as 10.56J, 20.08J)
Prereq.: 7.03 or 7.05; 5.60 or 10.13
U (2)
4-0-8

Biological and bioengineering principles for utilization of cultured animal cells and their protein products: post-translational processing and secretion of proteins; gene cloning and expression in mammalian cells; physiology of cell growth and in vitro cultivation; bioreactor design; protein recovery and purification; alternatives to mammalian cell culture; Federal regulatory issues; marketing and business planning; and issues in patents and laws.
A. J. Sinskey, D. I. C. Wang

7.53 Laboratory in Biological Ultrastructure

Prereq.: 7.06 or 7.08
U (1)
3-3-3

Organization of macromolecules into larger structures and cell organelles; structure and assembly of enzymes, viruses, ribosomes, microtubules, flagella and cilia, centrioles, muscle, cartilage, and bone. Instruction in operation of the electron microscope and techniques for preparing and visualizing biological samples. Image processing and analysis of ultrastructure from micrographs.
J. A. King

7.54 Human Physiology

Prereq.: 7.05
U (1)
4-0-8

Comprehensive course in human physiology, emphasizing the molecular basis and applied aspects of organ function and regulation in health and disease. Material covered includes a review of cell structure and function, as well as the mechanisms by which the endocrine and nervous systems integrate cellular metabolism. Special emphasis on examining the cardiovascular, pulmonary, gastrointestinal, and renal systems.
M. Krieger, R. D. Rosenberg

7.55J Reproductive Biology

(Same subject as SP 484J)
Prereq.: —
U (2) HASS
3-0-6

A rigorous introduction to aspects of molecular, cell, and developmental biology that pertain to human reproduction. Attendant ethical and social issues as they affect the lives of men and women are addressed. Includes Mendelian and molecular genetics, gamete formation and fertilization, the sex life of plants and animals other than humans, the sociology and biology of birth control, recombinant DNA technology, and gene therapy.
N. H. Hopkins, C. Whitbeck

7.60 Cell Biology I (A)

Prereq.: 7.08
G (2)
4-0-8

Structure and organization of genes and genomes, nucleic acid biosynthesis, structure and assembly of nuclei and chromosomes, regulation of cell cycle, DNA replication, RNA transcription, processing and translation, differentiation of specialized cell types. Text and literature readings.
P. A. Sharp, Staff

7.61 Cell Biology II (A)

Prereq.: 7.08
G (1)
4-0-8

Structure and function of membranes. Transport, channels, and pumps. Synthesis and processing of membrane and secreted proteins. Receptors, endocytosis, and recycling of membrane proteins. Cytoskeletal and extracellular matrix proteins; structure, function, and assembly. Intracellular organization and motility. Cell adhesion, morphology, and migration. Hormones, receptors, and second messengers in cellular recognition. Organization of specialized cell types. Text and literature readings.
R. O. Hynes, Staff

7.62 Tumor Biology (A)

Prereq.: 7.05
G (2)
3-0-9

Broadly concerned with the natural history and causal mechanisms of cancer in humans and animals. Subjects include differences between normal and tumor cells, viral and chemical carcinogenesis in cultured cells and in animals, activation of chemical carcinogens, chromosomal and genetic influences, monoclonal vs polyclonal tumors, malignant-normal cell hybrids, host-tumor interactions, tumor immunology, reversibility of malignant phenotype, causes and treatment of human cancer. Lectures and student papers.
H. E. Ruley, H. N. Eisen, B. H. Cochran

7.63 Immunology for Graduate Students (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Principles of immunology, including immunochemistry and molecular and cellular immunology. An in-depth critical analysis of current literature in the field. Particular attention paid to the function of the immune system as a whole as studied by modern methods and techniques. Discussions of original papers supplement lectures.
M. L. Gefter, D. H. Raulet, S. Tonegawa

7.66J Cellular and Molecular Biology of the Nervous System

(Same subject as 9.321J)
Prereq.: —
G (2)
2-0-4

A lecture course covering the concepts and methods used in analyzing the molecular basis of brain development and function. Specific topics covered include the control of gene expression in the brain, synaptic function and ionic signaling, development of invertebrate and vertebrate nervous systems.
A. Lander, R. D. G. McKay

7.67J Genetic Neurobiology (A) (New)

(Same subject as 9.322J)
Prereq.: —
G (2) **Not to be offered 1989-90**
3-0-6

See description under subject 9.322J.
W. G. Quinn, H. Steller

7.71J Biophysical Chemistry

(Same subject as 5.64J)
Prereq.: 5.60, 7.05
U (1)
3-0-9

Nucleic acids: structures and forces that stabilize them. Polymer statistics relating to properties of long nucleic acid chains. Supercoiling. Hydrodynamic behavior as a function of conformation. Melting of double-stranded DNA and RNA: helix-coil transition. Renaturation kinetics and Cot curves. Proteins: thermodynamics and kinetics of protein folding. Forces stabilizing three-dimensional structure. Hydrophobic effects and water structure. Prediction of structure from amino acid sequence. Enzyme kinetics and allosteric systems. Interactions with nucleic acids.
G. A. Petsko, P. Schimmel

7.73 General Immunology

Prereq.: 7.05
U (1)
4-0-8

A comprehensive survey of immunology. Includes antigen-antibody reactions, immunoglobulin structure, organization and expression of immunoglobulin genes, cells and tissues of the immune system, major histocompatibility complex (MHC), genes encoding MHC proteins and T-cell antigen-specific receptors, antibody formation, cell-mediated immunity, complement, hypersensitivity, immunodeficiencies, graft rejection.
H. N. Eisen, D. H. Raulet

7.75 Advanced Biochemistry (A)

Prereq.: 7.05
G (2)
4-0-8

Major metabolic pathways for the synthesis of amino acids, coenzymes, lipids, and steroids, emphasizing enzyme mechanisms, regulation, and coenzyme-catalyzed reactions. Oxidative phosphorylation and photosynthesis.
G. M. Brown, M. Krieger

7.77 Nucleic Acids and Their Interactions with Proteins (A)

Prereq.: 7.05 or 7.31
G (2)
3-0-9

Chemistry, structure, and function of DNA and RNA. Biochemical, physical, and genetic approaches to studies of nucleic acids. DNA conformation including A-, B-, and Z-forms. Superhelical and bent DNA. Protein-nucleic acid systems, including repressors and activators, nucleosomes, restriction enzymes, aminoacyl tRNA synthetases, ribosomes, and RNA polymerases. Catalysis by RNA. Mechanisms of transcription in prokaryotes and eukaryotes.
U. L. RajBhandary, P. Schimmel

7.78 Seminar in Lipid and Carbohydrate Biochemistry (A)

Prereq.: 7.05
G (2) **Not to be offered 1989-90**
2-0-4

Discusses recent research in the area of complex lipids and carbohydrates. Lipid topics include phospholipids, prostaglandins, and steroids. In the carbohydrate area, emphasizes membrane and cell surface components of bacteria, yeast, and animal cells. Format includes lectures, discussions of recent literature, and student reports.
P. W. Robbins

7.81 Frontiers in Modern Plant Biology (A)

Prereq.: 7.03, 7.05
G (1) [P/F]
3-0-9

Intensive analysis of key original literature, both classical and current, with emphasis on experimental approaches and analysis of primary data. Topics include regulation of cell, tissue, and organ growth; control of gene expression; fertility, embryogenesis, and seed development; transformation and transgenic plants; transposable elements and genetic structure; function and genetics of organelles; pathogenesis and disease resistance. Student reports and class presentations.
E. R. Signer, G. R. Fink

7.82 Selected Topics of Mammalian Development and Genetics

Prereq.: —
G (1)
2-0-4

Seminar course covering biological, genetic, and molecular approaches to mouse development. Topics include preimplantation development; postimplantation development; cell lineage studies; embryonic stem cells; transgenic mice; insertional mutagenesis; tissue interactions and induction; X-inactivation; sex determination; T-locus; genetic basis of coat color; hematopoiesis.
R. Jaenisch, H-S. Shin

7.86 Molecular Genetics (A)

Prereq.: 7.05, 7.27
G (2) [P/F] **Next offered 1989-90**
3-0-9

Examines in depth selected topics by study and discussion of the literature in seminar format. Special emphasis on experimental details supporting current ideas about replication of nucleic acids, genome organization, genetic recombination, and gene function as developed in microbial systems. Subject designed to establish familiarity with literature and patterns of thought in the field and develop ability to evaluate papers critically. Undergraduates who have taken 7.03 and 7.21 admitted with permission of instructor.
M. S. Fox

7.90 Special Problems in Biology for Undergraduates

Prereq.: —
U (1, 2)
Arr.

Program of study or research to be arranged with a Department faculty member. Written report required. Permission of Department required. Consult Department headquarters.

7.93 Selected Topics in Biology (A)

Prereq.: —
G (1 or 2) [P/F]
Arr.

Classwork in various fields of biology not covered by the regular subjects of instruction. Consult Department headquarters.

7.941 Research Problems (A)

Prereq.: —
G (1) [P/F]
Arr.

7.942 Research Problems (A)

Prereq.: —
G (2) [P/F]
Arr.

Directed research in a field of biological science, but not contributory to graduate thesis. Consult Department headquarters.

7.99 Molecular Configuration in Biological Systems Seminar (A)

Prereq.: 7.05
G (2)
2-0-4

Properties conferred on biochemical substances by assumption of specific physical configurations. Optical methods (emphasizing X-ray diffraction) for determining configuration in macromolecular systems. Special emphasis on molecular structure of crystalline proteins and nucleic acids.
A. Rich

Course 8 Physics

General Undergraduate Subjects

8 S25 Atoms, Quarks, and Cosmology (New)

Prereq.: 8.02
U (1)
2-0-4

Fundamentals of physics, with a global view. Behavior of gases and solids, photoelectric effect, X-ray and electron diffraction, and atomic spectroscopy. Fundamentals of quantum mechanics, wave-particle dualism, uncertainty principle, and particle spin. The structure of atoms, nuclei, and fundamental particles will be linked to the structure of the visible universe, using elementary classical and quantum ideas. Primary emphasis on general concepts, assuming only freshman-level mechanics and electromagnetism.
B. F. Burke

8 S63 Computer-Aided Physics Laboratory (New)

Prereq.: —
U (1, 2)
0-4-2

Computers are essential in physics experiments and in theoretical calculations that do not yield to analytical methods. Students in this seminar learn to use IBM PCs in both of these areas. Languages available are BASIC, FORTRAN, and Pascal, all with high-resolution computer graphics. A number of experiments in mechanics, electricity, magnetism, and other areas of physics use the computers for taking, plotting, and fitting theoretical functions to the data. Students are also taught numerical methods to solve nonideal physics problems. Also available on a limited basis as a Freshman Advisor Seminar.
E. L. Lomon

8.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in physics. For further information, contact the Departmental UROP Coordinator.
A. M. Bernstein

8.01 Physics I

Prereq.: —
U (1, 2)
5-0-7

Introduces classical mechanics. Space and time: straight-line kinematics; motion in a plane; forces and equilibrium; experimental basis of Newton's laws; particle dynamics; universal gravitation; collisions and conservation laws; work and potential energy; vibrational motion; conservative forces; inertial forces and non-inertial frames; central force motions; rigid bodies and rotational dynamics.
Term 1: *S. B. Kowalski*
Term 2: Information: S. A. Rappaport.

8.012 Physics I

Prereq.: —
U (1)
5-0-7

Elementary mechanics, presented at greater depth than in 8.01. Newton's laws, concepts of momentum, energy, angular momentum, rigid body motion, non-inertial systems. Uses elementary calculus freely. Concurrent registration in a math subject more advanced than 18.01 is recommended.
S. W. Stahler

8.02 Physics II

Prereq.: 8.01 or 8.012; 18.01
U (1, 2)
5-0-7

Introduction to electromagnetism and electrostatics: electric charge, Coulomb's law, electric structure of matter; conductors and dielectrics. Concepts of electrostatic field and potential, electrostatic energy. Electric currents, magnetic fields and Ampere's law. Magnetic materials. Time-varying fields and Faraday's law of induction. Basic electric circuits. Electromagnetic waves and Maxwell's equations.
Information: S. A. Rappaport

8.022 Physics II

Prereq.: 8.012
U (2)
5-0-7

Parallel to 8.02, but more advanced mathematically. Some knowledge of vector calculus assumed. Maxwell's equations, in both differential and integral form. Electrostatic and magnetic vector potential. Properties of dielectrics and magnetic materials.
D. Kleppner

8.03 Physics III

Prereq.: 8.02 or 8.021 or 8.022, 18.02
U (1, 2) SD
5-0-7

Mechanical vibrations and waves; simple harmonic motion, superposition, forced vibrations and resonance, coupled oscillations and normal modes; vibrations of continuous systems; reflection and refraction; phase and group velocity. Optics; wave solutions to Maxwell's equations; polarization; Snell's Law, interference, Huygens's principle, Fraunhofer diffraction, gratings.
Term 1: *L. G. Herten*
Term 2: Information: S. A. Rappaport

8.04 Quantum Physics I

Prereq.: 8.03 or 6.014, 18.03
U (1, 2) SD
5-0-7

Experimental basis of quantum physics: photoelectric effect, Compton scattering, photons, Franck-Hertz experiment, the Bohr atom, electron diffraction, deBroglie waves, wave-particle duality of matter and light. Introduction to wave mechanics: Schroedinger's equation, wave functions, wave packets, probability amplitudes, stationary states, the Heisenberg uncertainty principle and zero-point energies. Solutions to Schroedinger's equation in one dimension: transmission and reflection at a barrier, barrier penetration, potential wells, the simple harmonic oscillator.
Term 1: *R. L. Jaffe*
Term 2: *S. Cooper*

8.044 Statistical Physics I

Prereq.: 8.03, 18.03
U (2)
5-0-7

Introduction to probability, statistical mechanics, and thermodynamics. Random variables, joint and conditional probability densities, functions of a random variable. Concepts of macroscopic variables and thermodynamic equilibrium, fundamental assumption of statistical mechanics, microcanonical and canonical ensembles. First, second, and third laws of thermodynamics. Numerous examples illustrating a wide variety of physical phenomena such as magnetism, polyatomic gases, thermal radiation, electrons in solids, and noise in electronic devices. Concurrent enrollment in 8.04 is recommended.
J. M. Graybeal

8.05 Quantum Physics II

Prereq.: 8.04 or 8.211
U (1, 2)
5-0-7

Reviews the postulates of wave mechanics. Wave mechanics in two and three dimensions: the hydrogen atom. General formalism of quantum mechanics: state space, Dirac notation, representations, and matrix mechanics. Angular momentum, magnetic moments. Identical particles and the exclusion principle: many-electron atoms, the periodic table, simple molecules, Fermi and Bose gases. Perturbation theory: time-independent theory, variational principle, adiabatic and sudden approximations, time-dependent theory. Discusses real physical examples at each stage.
Term 1: *J. W. Negele*
Term 2: *R. L. Jaffe*

8.06 Mechanics II

Prereq.: 8.03
U (2)
4-0-8

Basic concepts of mechanics: inertial frames of reference; space, time, mass, force. Types of forces. Equations of motion; non-inertial frames of reference. Conservation laws for closed systems. Planetary motion. Harmonic oscillator. Macroscopic objects: constraints; Hamilton's principle and Lagrange's equations. Rigid body dynamics. Coupled oscillators, Green's functions. Normal modes; continuum limit; elastic strings, solids. Canonical variables, Hamilton's equations.
A. V. Manohar

8.07 Electromagnetism II

Prereq.: 8.03, 18.03
U (1)
4-0-8

Survey of basic electromagnetic phenomena: electrostatics, magnetostatics; electromagnetic properties of matter. Time-dependent electromagnetic fields and Maxwell's equations. Electromagnetic waves, emission, absorption, and scattering of radiation. Relativistic electrodynamics and mechanics.
B. Zwiebach

8.08 Statistical Physics II

Prereq.: 8.05
U (2)
4-0-8

Probability distributions for classical and quantum systems. Microcanonical, canonical, and grand canonical partition-functions and associated thermodynamic potentials. Conditions of thermodynamic equilibrium for homogenous and heterogenous systems. Applications: non-interacting Bose and Fermi gases; mean field theories for real gases, binary mixtures, magnetic systems, polymer solutions; phase and reaction equilibria, critical phenomena. Fluctuations, correlation functions and susceptibilities, Kubo formulae. Evolution of distribution functions: Boltzmann and Smoluchowski equations.
G. B. Benedek

Undergraduate Laboratory and Special Project Subjects

8.11 Physics Project Laboratory I

Prereq.: —
U (1) LAB
1-6-5

8.12 Physics Project Laboratory II

Prereq.: —
U (1, 2) LAB
1-6-5

Students carry out experimental projects of their own choice and design to study physical phenomena. Faculty help define projects and teach techniques and methods for setting up experimental apparatus, making measurements, verifying observations, and analyzing data. Prior experience in a laboratory environment not required. Projects in the past have included topics in optics, acoustics, interferometry, spectroscopy, microwave optics, particle counting, hydrodynamics, nuclear magnetic resonance, Hall effect, and quantum phenomena. Not usable as a restricted elective for physics majors.
R. K. Yamamoto

8.13 Experimental Physics I

Prereq.: 8.04 or 8.211
U (1)
0-6-9

8.14 Experimental Physics II

Prereq.: 8.04 or 8.211, *8.05*
U (2)
0-6-9

About five fundamental laboratory experiments carried out each term, covering most aspects of modern physics relating to names such as Rutherford, Franck-Hertz, Hall, Ramsauer, Doppler, Fraunhofer, Faraday, Mossbauer, Compton, Stern-Gerlach. Stresses basic experimental techniques and data analyses, and written and oral presentation of experiment results. Second term requires knowledge of quantum mechanics at the 8.05 level.
G. W. Clark

8.18 Special Problems in Undergraduate Physics

Prereq.: —
U (1, 2)
Arr.

Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member. Specific approval required in each case.
S. A. Rappaport

8.19 Readings in Physics

Prereq.: —
U (1, 2) [P/F]
Arr.

Supervised reading and library work. Choice of material and allotment of time according to individual needs. For students who want to do work not provided for in the regular subjects. Specific approval required in each case.
S. A. Rappaport

Undergraduate Elective Subjects

8.20 Introduction to Special Relativity

Prereq.: 8.01, *8.02, 18.01*
U (1) SD
2-0-7

Analyzes time stretching, Lorentz contraction, limiting speed of light, solutions to the twin paradox using invariance of the interval, Lorentz transformation, and space-time diagrams. Analyzes particle collisions, interactions, transformations, creations, and annihilations, using conservation laws and the energy-momentum 4-vector. Examples from MIT research projects. Puzzles and paradoxes. Briefly discusses the theory of gravitation (general relativity).
E. H. Farhi

8.202J Life and Institutions of Science (New — Context Subject)

(Same subject as STS 014J)
Prereq.: —
U (1)
3-0-9

An examination of the activity of science in three contexts: the personal experience context of "doing science"; the intellectual context of science as a way of thinking and knowing; and the social context in terms of the people who do science and the institutions in which it is done, the nature and basis of support for science, and the uses society makes of it. The main focus is on today's world, but provides historical perspective as well. Intended primarily for juniors and seniors in science and engineering. May *not* count toward HASS Requirement.
J. G. King, C. Kaysen

8.204J Does Technology Drive Politics?: The Decision to Build the H-Bomb (New — Context Subject)

(Same subject as 21.441J)
Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

In considering the relationship between science, technology, and society, no subject is more important or more illuminating than the decision of the US government in 1950 to develop the H-bomb in response to the first Soviet A-bomb test. The decision was made by President Truman and his advisors despite the recommendation of the Atomic Energy Commission. Students will study the physics and history of the era; each will research in depth one of the decision makers (e.g., Oppenheimer, Lillienthal, Acheson, Truman, and others). May *not* count toward HASS Requirement.
A. M. Bernstein, S. Deutsch

8.206J Engineers, Scientists, and Public Controversies (New — Context Subject)

(Same subject as 2.93J and STS 012J)
Prereq.: —
U (2)
3-0-9

Investigates the nature of controversies surrounding science and technology and the roles technical specialists play in their resolution. Students analyze the technical, social, political, and ethical context of public controversies through case studies documented by archival videotapes, readings, and testimony of guests. Cases may include the space shuttle accident, nuclear reactor safety, Star Wars, AIDS and other medical testing, and the release of environmental contaminants. May *not* count toward HASS Requirement.
B. T. Feld, C. Weiner, J. A. Fay

8.208 Nuclear War: Threat and Avoidance

Prereq.: —
U (2) HASS
3-0-6

Engineering School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

8.211 Introduction to Quantum Physics

Prereq.: 18.03, 8.02
U (1) SD
5-0-7

Introduces quantum physics, with application to atoms, molecules, and solids. Emphasizes failures of classical physics, experimental basis for quantum mechanics, and an understanding of the Uncertainty Principle. Applies Schroedinger's theory to the free particle, tunneling, the harmonic oscillator, and the hydrogen atom. Discusses Pauli Exclusion Principle, many-electron atoms, and quantum theory of ionic and covalent bonding. Not usable as a restricted elective for physics majors.
P. L. Hagelstein

8.231 Physics of Solids I

Prereq.: 8.044 or 6.018, 8.211 or 8.05
U (1)
4-0-8

First term of a sequence presenting basic concepts of the quantum theory of solids. Emphasizes simple physical models. Topics: periodic structure and symmetry of crystals; diffraction; reciprocal lattice; chemical bonding; lattice dynamics, phonons, thermal properties; free electron gas; nearly free electron approximation; tight binding approximation; semiconductors: electrons, holes, impurities; materials with s, p, d, and f electrons.
A. N. Berker

8.232 Physics of Solids II

Prereq.: 8.231 or 6.730
U (2)
4-0-8

Second term of solid-state physics, presenting basic concepts of the quantum theory of solids. Emphasizes simple physical models. Topics: electronic structures, dynamics of electrons in solids, Fermi surfaces, transport phenomena in metals and semiconductors; optical properties of metals, semiconductors, and insulators; lattice modes; magnetic phenomena in solids such as paramagnetism, diamagnetism, ferromagnetism; resonance studies in a magnetic field; superconductivity.
A. N. Berker

8.242 Quantum Electronics and Laser Spectroscopy

Prereq.: 8.04 or 8.211
U (2)
3-1-8

Fundamental processes in lasers and their applications to studying physical properties of atoms and molecules. Interaction of classical and quantum systems with electromagnetic radiation. The physics of two-level atoms. Laser oscillators. Techniques in nonlinear spectroscopy, such as stimulated Raman effect, free induction decay, optical nutation, photon echoes, and CARS. As part of the curriculum, each student is required to carry out a laboratory project. Familiarity with Maxwell's equations and the Schroedinger equation is required.
M. S. Feld

8.243 Modern Optics

Prereq.: 8.03
U (1) SD **Next offered 1989-90**
3-0-9

Ray matrices, reflection and refraction at dielectric interface. Fresnel equations, Gaussian beams, optical resonators. Fiber optics. Propagation in anisotropic media, optical activity, electro-optics, and magneto-optic effects. Propagation in nonlinear media, effects of second-and third-order nonlinear susceptibility. Interference, Michelson and Fabry-Perot interferometers, Fourier transform spectroscopy, multi-layer films. Fraunhofer and Fresnel diffraction. Diffraction gratings. Fourier optics, spatial filtering, holography.
R. L. Aggarwal

8.263 Physics of Fluids

Prereq.: 8.03
U (1) SD **Next offered 1989-90**
3-0-9

Introduction to the physics of fluids. Emphasis on phenomena rather than mathematics. Topics: physical properties of liquids, gases, plasmas. Dynamics, waves, and turbulence.
K. U. Ingard

8.276 Nuclear and Particle Physics

Prereq.: 8.05
U (2) **Next offered 1989-90**
4-0-8

A modern view of the fundamental structure of matter. Starting from a model that views "quarks" as basic building blocks of mesons and baryons, the properties and interactions of these particles are established. Quantum numbers and multiplet structure of particle families. Nuclei as multibaryon systems: stability, radioactive decay, reactions. Current topics in nuclear and particle physics research at MIT. Information: S. A. Rappaport

8.282 Introduction to Astrophysics and Astronomy

Prereq.: —
U (2) SD
3-0-9

Quantitative introduction to physics of the galaxy and the universe, as determined from a variety of astronomical observations and from cosmic ray and neutrino experiments. Topics: the sun and "normal" stars, supernovae, pulsars, globular clusters, compact objects (white dwarfs, neutron stars, black holes), optical and X-ray stellar binary systems, interstellar medium and star formation, galaxies, quasars, and cosmology. Prior knowledge of astronomy not necessary. Not usable as a restricted elective by physics majors.
S. W. Stahler, S. A. Rappaport

8.284 Modern Astrophysics

Prereq.: 8.04, *8.05*
U (1)
3-0-9

Applications of physics (Newtonian, statistical, and quantum mechanics) to fundamental processes that occur in celestial objects. Includes main-sequence stars, collapsed stars (white dwarfs, neutron stars, and black holes), pulsars, supernovae, the interstellar medium, galaxies, and as time permits, active galaxies, quasars, and cosmology. Observational data discussed. No prior knowledge of astronomy is required.
H. Bradt

8.286 The Early Universe

Prereq.: 18.03, 8.02
U (2) SD **Next offered 1989-90**
3-0-9

Introduction to modern cosmology. First half deals with the development of the big-bang theory from 1915 to 1980, and latter half with recent impact of particle theory. Topics: special relativity and the Doppler effect, Newtonian cosmological models, introduction to non-Euclidean spaces, thermal radiation and early history of the universe, big-bang nucleosynthesis, introduction to grand unified theories and other recent developments in particle theory, baryogenesis, the inflationary universe model, and the evolution of galactic structure.
A. H. Guth

8.287J Observational Techniques of Optical Astronomy

(Same subject as 12.117J)
Prereq.: One subject in Astronomy or Astrophysics
U (1) LAB
3-4-5

See description under subject 12.117J.
J. L. Elliot

8.291J Planetary Science I

(Same subject as 12.131J)
Prereq.: 8.03, 18.03
U (1) SD
3-0-9

See description under subject 12.131J.
D. C. Jewitt

8.292J Planetary Science II

(Same subject as 12.132J)
Prereq.: 12.131J or 8.291J
U (2) SD **Next offered 1989-90**
3-0-9

See description under subject 12.132J.
D. C. Jewitt

8.293J Dynamical Astronomy

(Same subject as 12.126J)
Prereq.: 18.03, 8.03
U (2) SD
3-0-9

See description under subject 12.126J.
J. Wisdom

8.299 Physics Teaching

Prereq.: —
U (1, 2) [P/F]
Arr.

For qualified undergraduate students interested in gaining some experience in teaching. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview.
S. A. Rappaport

8. ThU Undergraduate Physics Thesis

Prereq.: —
U (1, 2, S)
Arr.

Program of undergraduate research, leading to the writing of an S.B. thesis; to be arranged by the student under approved supervision.
A. M. Bernstein

Graduate Subjects

An asterisk (*) denotes subjects not routinely offered; they will be given when sufficient interest is indicated.

General and Mathematical Physics

8.312 Electromagnetic Theory (A)

Prereq.: 8.07
G (2)
4-0-8

Basic principles of electromagnetic theory: Maxwell's equations; vector and scalar potentials; conservation laws, methods in electro- and magnetostatics. Scattering and diffraction of electromagnetic waves. Theory of special relativity; covariant formulation of Maxwell's equations. Motion of relativistic particles in electric and magnetic fields. Collisions and energy loss. Cerenkov radiation. Radiation by moving charges; synchrotron radiation. Bremsstrahlung. Radiation damping; self-fields of a particle. Information: J. Goldstone.

8.321 Quantum Theory I (A)

Prereq.: 8.05, 8.06
G (1)
4-0-8

8.322 Quantum Theory II (A)

Prereq.: 8.07, 8.321
G (2)
4-0-8

A two-semester subject on quantum theory, stressing principles: uncertainty relation, observables, eigenstates, eigenvalues, probabilities of the results of measurement, transformation theory, equations of motion, constants of motion. Symmetry in quantum mechanics, representations of symmetry groups. Variational and perturbation approximations. Systems of identical particles and applications. Time-dependent perturbation theory. Scattering theory: phase shifts, Born approximation. The quantum theory of radiation. Second quantization and many-body theory. Relativistic quantum mechanics of one electron.
R. W. Jackiw

8.323 Relativistic Quantum Field Theory I (A)

Prereq.: 8.322
G (1)
4-0-8

8.324 Relativistic Quantum Field Theory II (A)

Prereq.: 8.323
G (2)
4-0-8

A two-semester course on relativistic quantum field theory, stressing the formulation of gauge field theory and application to fundamental physical problems. Classical field theory, canonical quantization, the Dirac field. Interacting fields and perturbation theory, Feynman graphs. Symmetries. Calculations in quantum electrodynamics. Functional integral formation of gauge theories. Divergences, regularization, and renormalization. Higher-order processes in electrodynamics. Fundamental constituents of matter: the standard models of electroweak and strong interaction. Non-abelian gauge theories, spontaneous symmetry breakdown, the Goldstone and Higgs mechanisms. The Weinberg-Salam theory. Renormalization group.
J. Polonyi

8.333 Statistical Mechanics I (A)

Prereq.: 8.321
G (1)
4-0-8

8.334 Statistical Mechanics II (A)

Prereq.: 8.333
G (2)
4-0-8

A two-semester course on statistical mechanics. Basic principles are examined in 8.333: The laws of thermodynamics and the concepts of temperature, work, heat, and entropy. Postulates of classical statistical mechanics, micro-canonical, canonical, and grand canonical distributions; applications to lattice vibrations, ideal gas, photon gas. Quantum statistical mechanics; Fermi and Bose systems. Interacting systems: cluster expansions, van der Waal's gas, mean-field theory. Topics from modern statistical mechanics are explored in 8.334: The hydrodynamic limit and classical field theories. Phase transitions and broken symmetries: universality, correlation functions and scaling theory. The renormalization approach to collective phenomena. Dynamic critical behavior. Random systems.
M. Kardar

8.361 Quantum Theory of Many-Particle Systems (A)

Prereq.: 8.322, 8.333
G (1) **Not to be offered 1989-90**
3-0-9

Introduces general many-body theory applicable to low temperature, nuclear, and solid-state physics. Reviews occupation number representation and classical Mayer expansion. Perturbation theory: diagrammatic expansions and linked-cluster theorem for zero or finite temperature systems of fermions or bosons. Green's functions: analytic properties, equations of motion, relation to observables, approximations, linear response theory, random phase approximation. Superconductivity: electron-phonon interaction, instability of normal state, BCS ground state, perturbation theory.
G. Kotliar

8.381, 8.382 Selected Topics in Theoretical Physics (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Topics of current interest in theoretical physics, varying from year to year. Information: G. F. Koster.

8.391, 8.392 Special Problems in Graduate Physics (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

Advanced problems in any area of experimental or theoretical physics, with assigned reading and consultations.
G. F. Koster

8.399 Physics Teaching (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

For qualified graduate students interested in gaining some experience in teaching. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview.
G. F. Koster

Physics of Atoms, Radiation, Solids, Fluids, and Plasmas

8.421 Atomic and Molecular Physics (A)

Prereq.: 8.05
G (1)
3-0-9

The interaction of radiation with atoms: resonance; absorption, stimulated, and spontaneous emission; dressed atom formalism; multiphoton processes; structure of simple atoms; interactions with strong electric and magnetic fields. Additional topics vary from year to year: Lamb shift, atomic tests of basic theory, measurements of the fundamental constants, "cavity quantum electrodynamics," four-wave mixing, coherence, atom-atom interaction, atomic and molecular collisions.
D. Kleppner

8.481, 8.482 Selected Topics in Physics of Atoms and Radiation (A)

Prereq.: 8.321
G (1, 2)
3-0-9

Presentation of topics of current interest, with content varying from year to year. Information: G. F. Koster.

8.510J Application of Group Theory to the Physics of Solids (A)

(Same subject as 6.734J)
Prereq.: 8.232 or 6.732
G (2) **Next offered 1989-90**
3-0-9

See description under subject 6.734J.
M. S. Dresselhaus

8.511J Theory of Solids I (A)

(Same subject as 6.741J)
Prereq.: 8.232 or 6.732
G (1)
3-0-9

First term of a theoretical treatment of the physics of solids. Concept of elementary excitations. Symmetry: translational, rotational, and time-reversal invariances: theory of representations. Energy bands: APW, OPW, pseudopotential and LCAO schemes. Survey of electronic structure of metals, semimetals, semiconductors, and insulators. Excitons. Critical points. Response functions. Interactions in the electron gas.
J. Joannopoulos

8.512J Theory of Solids II (A)

(Same subject as 6.742J)
Prereq.: 8.232, 8.511J
G (2)
3-0-9

Second term of a theoretical treatment of the physics of solids. Interacting electron gas: many-body formulation, Feynman diagrams, random phase approximation and beyond. General theory of linear response: dielectric function; sum rules; plasmons; optical properties; applications to semiconductors, metals, and insulators. Transport properties: non-interacting electron gas with impurities, diffusons. Quantum Hall effect: integral and fractional. Electron-phonon interaction: general theory, applications to metals, semiconductors and insulators, polarons, field-theory description. Superconductivity: experimental observations, phenomenological theories, B.C.S. theory.
J. Joannopoulos

8.532J Physics of Semiconductors and Devices (A)

(Same subject as 6.735J)
Prereq.: 6.732 or 8.232
G (1)
3-0-9

Transport, optical, and magnetic properties of semiconductors, Quantum wells, superlattices, 2-D electron systems, quantized Hall effect, intercalation, semiconductor-metal transition, tunneling, physics of MOS devices, ion implantation, laser annealing, amorphous semiconductors, organic conductors, magnetic semiconductors, liquid crystals, localization phenomena, Bohm-Aharanov effect, nonlinear spectroscopy, two-photon absorption, Raman scattering.
M. S. Dresselhaus

8.562 Correlations and Critical Behavior in Condensed Matter (A)

Prereq.: 8.511J, 8.333
G (2) **Not to be offered 1989-90**
3-0-9

Views condensed-matter physics through space-and time-dependent correlation functions measured by scattering spectroscopy. Treats in detail experimental techniques of x-ray, light, electron, and neutron scattering. Theoretical development is strongly phenomenological to elucidate physical behavior with minimal mathematical complexity. Uses conservation laws, broken symmetry, and the fluctuation-dissipation theorem to illustrate the interconnection between apparently diverse systems, with special attention to behavior near phase transitions.
S. Mochrie

8.571 Theory of Phase Transitions in Macromolecular Solutions (New)

Prereq.: —
G (1)
3-0-9

Statistical mechanics used to provide a unified description of the experimental properties of a broad variety of macromolecular systems that exhibit phase transitions and critical phenomena. Systems studied include: (a) magnetically coupled spins, (b) binary mixtures of organic molecules, (c) gas-liquid transition in a pure fluid, (d) solutions of amphiphiles, micelles, and microemulsions, and (e) polymer solutions. The central role of fluctuations stressed and the connection between the fluctuations and the equilibrium susceptibilities established.
G. B. Benedek

8.581, 8.582 Selected Topics in Physics of Solids

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Presentation of topics of current interest, with contents varying from year to year. Information: G. F. Koster

8.613J Introduction to Plasma Physics I (A)

(Same subject as 6.651J, 22.611J)
Prereq.: 6.014 or 8.07; 6.018 or 8.044; 18.04 or 18.075
G (1)
3-0-9

Introduces plasma phenomena relevant to energy generation by controlled thermonuclear fusion and to astrophysics. Coulomb collisions and transport processes. Motion of charged particles in magnetic fields; plasma confinement schemes. MHD models; simple equilibrium and stability analysis. Two-fluid hydrodynamic plasma models; wave propagation in a magnetic field. Introduces kinetic theory; Vlasov plasma model; electron plasma waves and Landau damping; ion-acoustic waves; streaming instabilities.
M. Porkolab, A. Bers

8.614J Introduction to Plasma Physics II (A)

(Same subject as 6.652J, 22.612J)
Prereq.: 6.651J or 8.613J or 22.611J, 18.076
G (2)
3-0-9

See description under subject 22.612J.
A. Bers, R. C. Davidson, K. Molvig

8.621J Plasma Kinetic Theory (A)

(Same subject as 22.64J)
Prereq.: 8.613J
G (1)
3-0-9

Basic physics of the wave-particle interaction with emphasis on intuitive concepts. Linearized Vlasov equation, quasilinear theory, Fokker-Planck and diffusion approximations for the average distribution function, resonant and nonresonant diffusion, energy and momentum conservation, free energy, application of quasilinear theory to various physical problems of current interest.
T. H. Dupree

8.622J Advanced Topics in Plasma Kinetic Theory (A)

(Same subject as 22.65J)
Prereq.: 8.621J or 22.64J
G (2)
3-0-9

Vlasov, Liouville, and Klimontovich equations, hierarchy equations and correlation functions, discrete particle effects, test particle model, fluctuation-dissipation theorem, collision integrals. Direct Interaction Approximation and other renormalized theories, onset of stochasticity, nonlinear dielectric functions, nonlinear stabilization of linear instabilities, resonance broadening, mixing, clumps, mode coupling, solitons, BGK modes, nonlinear instabilities.
T. H. Dupree

8.624 Waves, Instabilities, and Radio-Frequency Heating of Plasmas and Nonlinear Effects (A)

Prereq.: 8.613J
G (2) **Next offered 1989-90**
3-0-9

Comprehensive theory of electromagnetic waves in a magnetized plasma. Effects of finite temperature including linear mode-conversion. Vlasov theory of waves and instabilities in a hot, magnetized plasma. Bernstein waves, drift waves, gravitational modes, and loss-cone modes. Electromagnetic waves in a hot plasma, with applications to radio-frequency heating of fusion plasmas (ECRH, ICRH, LHH). RF current drive in tokamaks. Parametric instabilities. Discusses relevant experimental results.
M. Porkolab

8.641 Physics of High-Energy Plasmas I (A)

Prereq.: 8.613J
G (1) **Not to be offered 1989-90**
3-0-9

8.642 Physics of High-Energy Plasmas II (A)

Prereq.: 8.613J
G (1) **Next offered 1989-90**
3-0-9

Basic concepts of plasmas, with temperatures of thermonuclear interest, relevant to fusion research and astrophysics. Microscopic transport processes due to inter-particle collisions and collective modes (e.g., microinstabilities). Relevant macroscopic transport coefficients (electrical resistivity, thermal conductivities, particle "diffusion"). Runaway and slide-away regimes. Magnetic reconnection processes and their relevance to experimental observations. Radiation emission from inhomogeneous plasmas. Conditions for thermonuclear burning and ignition (D-T and "advanced" fusion reactions, plasmas with polarized nuclei). Role of "impurity" nuclei. "Finite-β" (pressure) regimes and ballooning modes. Convective modes in configuration and velocity space. Trapped particle regimes. Nonlinear and explosive instabilities. Interaction of positive and negative energy modes. Each subject can be taken independently.
B. Coppi

8.681, 8.682 Selected Topics in Fluid and Plasma Physics (A)

Prereq.: 8.613J
G (1, 2)
3-0-9

Presentation of topics of current interest, with content varying from year to year. Information: G. F. Koster.

Nuclear and Particle Physics

8.710 Introduction to Nuclear Physics (A)

Prereq.: 8.321
G (2)
3-0-9

Comprehensive survey of nuclear structure and dynamics. Properties of the nuclear force. Interpretation of experimental data via specific many-body models. Independent particle motion in spherical and deformed nuclei and its microscopic basis. Correlations. Electromagnetic probes: muonic atoms, electron scattering. photon reactions, moments. Collective motion and giant resonances. Hadronic probes: direct and compound reactions. β-decay. Sum rules. Heavy ion reactions. Evidence for meson currents and quark-gluon substructure. Nuclear astrophysics. Experimental methods. Accelerators. Current topics.
W. Bertozzi

8.711 Nuclear Physics (A)

Prereq.: 8.321, 8.710
G (1)
4-0-8

Advanced course in experimental foundations and theoretical understanding of the structure of nucleons and nuclei. Hadron structure: evidence for quarks and their properties; symmetries and classification of states; quark models of the nucleon. Nucleon-nucleon scattering; phenomenological potentials and meson exchange theories; quark models of nuclear forces. Nuclear matter: Brueckner theory; correlations. Shell model and effective interactions; core polarization; pairing, Hartree-Fock description of spherical and deformed nuclei; collective motion. Phases of hadronic matter.
M. Baranger

8.712 Advanced Topics in Nuclear Physics (A)

Prereq.: 8.711 or Permission of Instructor
G (2)
4-0-8

Course for experimentalists and theorists with the following rotation of topics:
Medium-energy physics (spring, 1989): Nuclear and nucleon structure and dynamics studied with intermediate- and high-energy probes (photons, electrons, nucleons, pions, and kaons).
Nuclear chromodynamics (spring, 1990): Introduction to QCD; structure of nucleons; lattice QCD; phases of hadronic matter and relativistic heavy ion collisions.
Reaction theory (spring, 1991): Coupled-channel theory; projection operator analysis; statistical model; elastic, inelastic, and transfer reactions; microscopic theory of multiple scattering and the optical potential.
E. J. Moniz

8.731 Nuclear Physics Seminar (A)

Prereq.: 8.322, 8.712
G (1) [P/F]
2-0-4

Advanced seminar on current topics. Short presentations by both experimentalists and theorists. Emphasis varies yearly. Typical topics: ultrarelativistic heavy-ion collisions; quark models of nucleons, nuclei, and nucleon-nucleon interaction; new observables in electron scattering, using polarized beams, polarized targets, and coincidence measurements; recent experiments on relativistic nucleon-nucleon scattering; developments in many-body theory, including functional integral and stochastic methods. Information: W. Bertozzi.

8.781, 8.782 Selected Topics in Nuclear Theory (A)*

Prereq.: 8.751
G (1, 2)
3-0-9

Presents topics of current interest in nuclear structure and reaction theory, with content varying from year to year.
Information: G. F. Koster.

8.810 Particle Physics I (A)

Prereq.: 8.321, 8.322
G (1)
4-0-8

Introduces phenomenology of particle properties and interactions, stressing experimental results. Classification by quantum numbers. Isospin concept, symmetries; conservation laws. Particle detectors and techniques. Accelerators. Quark model, color symmetry, Dirac equation, and QED. V-A theory. Conservation-violation; parity, etc., experiments. K-mesons, associated production, puzzles, mixing, regeneration, CP-violation.
L. S. Osborne

8.811 Particle Physics II (A)

Prereq.: 8.810
G (2) **Next offered 1989-90**
3-0-9

New experiments and data. New machines, detectors, technologies; p-$\bar{p}$ and e^+-e^- colliders. Discovery of the W and Z, search for new particles and quarks. Neutrino physics. Tests of QED, the unified electroweak theory, quantum chromodynamics and Grand Unified Theories; proton decay. Phenomena at extremely high energies.
U. J. Becker

8.871, 8.872 Selected Topics in Theoretical Particle Physics (A)*

Prereq.: 8.323
G (1, 2)
3-0-9

Presents topics of current interest in theoretical particle physics, with content varying from year to year. Information: G. F. Koster.

8.881, 8.882 Selected Topics in Experimental Particle Physics (A)*

Prereq.: 8.811
G (1, 2)
3-0-9

Presents topics of current interest in experimental particle physics, with content varying from year to year. Information: G. F. Koster.

Space Physics and Astrophysics

8.910 Astrophysics (A)

Prereq.: 8.05, 8.08
G (2)
3-0-9

Size and time scales in astrophysics. Stellar structure equations and survey of stellar evolution. Degenerate stars and interacting binary stars. Radiative transfer, line formation, spectroscopy of interstellar medium. The equilibrium of stellar systems and the distribution of stars in our galaxy. Introduces cosmology.
J. L. Tonry

8.911 Astrophysical, Space, and Laboratory Plasmas, Theoretical Foundations and Comparative Study (A)

Prereq.: 8.07, 18.04, 18.302 or equivalent
G (1)
3-0-9

Part I: Fundamentals for plasmas on all scales: astrophysical, heliospheric, magnetospheric, ionospheric, and laboratory domains. Phase space distributions, Boltzmann and Vlasov-Maxwell equations, Fokker-Planck approximation. Adiabatic invariants, guiding center motion, conservation laws, virial theorem, collision-dominated plasmas, Onsager relations.
Part II: Approximations based on scales: MHD approximation, closure problem and breakdown of differential fluid equations, discontinuities and shocks, fluctuations, linear waves.
J. W. Belcher

8.913 Physics of Space Plasmas I (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

8.914 Physics of Space Plasmas II (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

For students interested in space physics, astrophysics, and plasma physics in general. Magnetospheres of rotating magnetized planets, ordinary stars, neutron stars, and black holes. Pulsar models: processes for slowing down, particle acceleration, and radiation emission; accreting plasmas and x-ray stars; stellar winds; heliosphere and solar wind: relevant magnetic field configuration, measured particle distribution in velocity space

and induced collective modes; stability of the current sheet and collisionless processes for magnetic reconnection; theory of collisionless shocks; solitons; Ferroaro-Rosenbluth sheet; solar flare models; heating processes of the solar corona; earth's magnetosphere (auroral phenomena and their interpretation, bow-shock, magnetotail, trapped particle effects); relationship between gravitational (galactic) plasmas and electromagnetic plasmas. 8.913 deals with heliospheric, 8.914 with extra-heliospheric plasmas.
B. Coppi

8.921 Stellar Structure and Evolution (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Observable stellar characteristics; overview of observational information. Principles underlying calculations of stellar structure. Physical processes in stellar interiors; properties of matter and radiation; radiative, conductive, and convective heat transport; nuclear energy generation; nucleosynthesis; neutrino emission. Protostars; the main sequence, and the solar neutrino flux; advanced evolutionary stages; variable stars; planetary nebulae, supernovae, white dwarfs, and neutron stars; close binary systems; abundance of chemical elements.
P. C. Joss

8.922 Physics of the Galaxy (A)

Prereq.: 8.910
G (2) **Not to be offered 1989-90**
3-0-9

Observations of the distribution of stars, clusters, gas, and dust in the galaxy. Theory of the equilibrium of stellar systems: Vlasov equation, Fokker-Planck equation, Jeans's theorem, and the third integral. Introduces spiral structure theory. Interstellar clouds, evolution of supernova envelopes, star formation, and the energy budget of the interstellar medium. Permission of instructor required. Information: P. C. Joss

8.923 High-Energy Astrophysics (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1989-90**
3-0-9

Observation and theory of high-energy phenomena in astrophysics. Reviews special relativity. Synchrotron radiation. Compton processes. Bremsstrahlung radiation. Coherent radiation processes. Radio pulsars. Cosmic rays origin, acceleration, and confinement. Supernovae. Shock waves. X-ray sources — spherical and disk accretion, diffuse x-ray emission. Quasars and Seyfert galaxies. Permission of instructor required.
P. Morrison

8.931J Radar Astronomy, Astrometry, and Geodesy (A)

(Same subject as 6.662J, 12.620J)
Prereq.: 8.03 or 6.014, 18.075 or 18.085
G (1) **Next offered 1989-90**
3-0-9

See description under subject 12.620J.
G. H. Pettengill, C. C. Counselman, D. H. Staelin

8.942 Cosmology (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Thermal backgrounds in space. Cosmological principle and its consequences: Newtonian cosmology and types of "universes"; survey of relativistic cosmology; horizons. Overview of evolution in cosmology; radiation and element synthesis; physical models of the "early stages." Formation of large-scale structure to variability of physical laws. First and last states. Some knowledge of relativity expected. 8.962 recommended though not required.
E. W. Bertschinger

8.952 Particle Physics of the Early Universe (A)

Prereq.: 8.323, 8.324
G (2) **Not to be offered 1989-90**
3-0-9

Thermal equilibrium states in quantum field theories. Phase transitions and the fate of the false vacuum. Homotopy theory and topological defects: monopoles, strings, and domain walls. The standard cosmological model. The inflationary universe. Quantum field theory in de Sitter space. Quantum origin of density fluctuations in inflationary models.
A. H. Guth

8.962J General Relativity (A)

(Same subject as 18.295J)
Prereq.: 18.06, 8.06, 8.312
G (2)
3-0-9

See description under subject 18.295J.
N. P. Warner

8.981, 8.982 Selected Topics in Astrophysics (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
3-0-9

Topics of current interest, varying from year to year. Information: G. F. Koster.

8.ThG Graduate Physics Thesis (A)

Prereq.: —
G (1, 2, S)
Arr.

Program of graduate research, leading to the writing of an S.M., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member.
G. F. Koster

Course 9

Brain and Cognitive Sciences

9.UR Undergraduate Research

Prereq.: —
U (1, 2, S) [P/F]
Arr.

Individual participation in an ongoing research project. For students in the Undergraduate Research Opportunities Program.
C. Atkeson

9.00 Introduction to Psychology

Prereq.: —
U (1) HASS-D
4-0-8

A survey of the study of human mental life and behavior. Explores sensation, perception, learning, memory, thinking, feeling, emotion, motivation, personality. Uses psychological, social, and biological data. Considers cultural, political, and literary impact of psychology. Examines controversies about mental illness, IQ, sex roles, fairy tales, and lie detectors.
J. M. Wolfe

9.01 Neuroscience and Behavior

Prereq.: 9.00 or 9.62J
U (1) HASS
3-0-9

Relation of structure and function at various levels of neuronal integration. Topics include: functional neuroanatomy and neurophysiology, motor systems, centrally programmed behavior, sensory systems, arousal, sleep and dreaming, motivation and reward, emotional displays of various types, "higher functions" and the neocortex, and neural processes in learning and memory. May be counted toward HASS Requirement *only* by students concentrating in Psychology; see Department for details.
N. Y.-S. Kiang

9.014J The Human Nervous System: The Neurosciences (A)

(Same subject as HST 131J)
Prereq.: Permission of Instructor
G (1)
6-3-6

See description under subject HST 131J.
A. M. Graybiel, W. G. Quinn, M. Sur, P. H. Schiller, E. Bizzi, and others

9.019 Introduction to Behavioral Neuroscience (A)

Prereq.: 9.014J
G (2) **Not to be offered 1989-90**
3-0-6

Integrates classical and current research on the effects of brain insult on human and animal behavior. Emphasizes specific neural mechanisms underlying memory, attention, language, perception, spatial abilities, motivation, and emotion. Also includes hemispheric specialization and the role of neurotransmitters and hormones in brain diseases. Some lectures include demonstrations of behavioral testing methods and presentations of patients. Alternate years.
S. Corkin

9.024 Development and Plasticity of the Visual System (A)

Prereq.: —
G (2) **Next offered 1989-90**
3-0-6

Topics include recent discoveries and promising research directions bearing on development of the visual system. Focuses on anatomical, physiological, behavioral, and theoretical approaches to visual function in higher mammals, including man. Alternate years.
M. Sur, R. Held, S. Jhaveri, G. E. Schneider

9.027 Biochemistry and Pharmacology of the Neurotransmitters (A) (New)

Prereq.: 9.014J
G (2) **Next offered 1989-90**
3-0-9

Considers the neurotransmitters and other compounds that mediate communications among neurons, and between neurons and other cells. Discusses experimental criteria for identifying these compounds; the best-known candidates; the processes controlling their synthesis, release, and metabolism in the body; their receptors; their responses to circulating chemicals (drugs, nutrients, hormones, toxins); and their involvement in diseases and in physiological and behavioral mechanisms. Alternate years.
R. J. Wurtman

9.029 Cellular Physiology (A) (New)

Prereq.: —
G (2)
3-0-6

Focuses on combined biochemical, molecular, and biophysical approaches to investigate the physiology of excitable membranes. Emphasis is on structure, function, and regulation of membrane ion channels. Permission of instructor required.
I. Levitan

9.030 Cerebral Cortex (A) (New)

Prereq.: —
G (2) **Not to be offered 1989-90**
3-0-6

A general survey of the structure and function of the cerebral cortex. Topics include cortical anatomy, functional localization, and newer computational approaches to understanding cortical processing operations. Motor cortex, sensory cortex (visual, auditory, and somatosensory cortex), association cortex and limbic cortex. Emphasis is on using animal models to understand human cortical function and includes correlations between animal studies and human neuropsychological literature. Alternate years.
R. Andersen

9.036 The Visual System (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

Reviews the current neurophysiological and neuroanatomical research literature on the mammalian visual system. Alternate years.
P. H. Schiller

9.06 Conflicting Images of Humanity and Nature

Prereq.: —
U (1) HASS
3-0-6

More than five billion and growing, we humans are straining the earth's natural resources to an unprecedented extent. How do ideas about nature and human nature relate to this crisis? We consider this question in historical perspective and in the light of recent developments in the natural and social sciences.
S. L. Chorover

9.09J Cellular Neurobiology

(Same subject as 7.09J)
Prereq.: 7.05
U (2)
4-0-8

See description under subject 7.09J.
S. J. Burden, R. D. G. McKay, W. G. Quinn

9.20 Animal Behavior

(9.30)
Prereq.: 9.00
U (1) HASS
3-0-6

Reviews basic concepts in the study of animal behavior. Addresses selected problems, including animal learning, cognition and communication, navigation, sexual behavior, aggression, domestication, foraging and feeding, defense against predation, perception, and learning. Examines the interacting contributions of environment and heredity to the shaping of behavior and for meeting the requirements for individual and species survival.
A. Hein

9.201 Advanced Animal Behavior (A) (New)

Prereq.: 9.20 or equivalent
G (2) **Not to be offered 1989-90**
3-0-6

Survey and special topics designed for graduate students in the brain and cognitive sciences. Emphasizes ethological studies of natural behavior patterns and their analysis in laboratory work, with contributions from field biology (mammology, primatology), sociobiology, and comparative psychology. Stresses mammalian behavior but also includes major contributions from studies of other vertebrates and of invertebrates. Also covers applications of animal-behavior knowledge to neuropsychology and behavioral pharmacology. Alternate years.
G. E. Schneider

9.320J Analysis of Differentiation and Development

(Same subject as 7.32J)
Prereq.: 7.05 or 7.33
G (2) [P/F]
3-0-9

See description under subject 7.32J.
M. L. Pardue, W. G. Quinn

9.321J Cellular and Molecular Biology of the Nervous System

(Same subject as 7.66J)
Prereq.: —
G (2)
2-0-4

See description under subject 7.66J.
S. J. Burden, R. D. G. McKay, A. Lander

9.322J Genetic Neurobiology (A) (New)

(Same subject as 7.67J)
Prereq.: —
G (2) **Not to be offered 1989-90**
3-0-6

Deals with the specific functions of neurons, the interactions of neurons in development, and the organization of neuronal ensembles to produce behavior, by functional analysis of mutations and molecular analysis of their genes. Concentrates on work with nematodes and fruit flies. Alternate years.
W. G. Quinn, H. Steller

9.345 Current Topics in Visual Neuroscience (New)

Prereq. —
G (1)
2-0-4

Reading and discussion of current publications in the fields of neurophysiology, psychophysics, anatomy, and computational neuroscience as they relate to the study of the mammalian visual system. Each student is required to make a one-hour presentation of recent work taken from the literature. Permission of the instructor is required for undergraduate students.
R. Andersen

9.35 Perceptual Information Processing

Prereq.: 9.00 or 9.62J
U (2)
3-0-6

The senses are our gateways to the world. Everything we know about what is going on out there comes to us through vision, hearing, touch, taste, smell. How do the senses work? How do physical stimuli get transduced into signals in the nervous system? How can the brain use those signals to determine the flavor of a banana, the sound of a flute, or the shape of a cow? All senses discussed. Vision is covered most extensively. Includes perception of color, motion, form and depth, individual differences, and development.
R. Held

9.351 Human Vision (A)

Prereq.: 9.35
G (2) **Next offered 1989-90**
3-0-9

Covers major issues and basic findings in the study of human vision. Emphasis is on results from psychophysical experimentation, with other material drawn from physiological and computational approaches. Lecture course for Course IX graduate students, but open to undergraduates with sufficient background. Alternate years. Permission of instructor required for students without 9.35 background.
J. M. Wolfe

9.358J Image Representation for Vision (A)

(Same subject as 4.906J)
Prereq.: Permission of Instructor
G (2)
2-0-7

See description under subject 4.906J.
E. H. Adelson

9.36 Natural Computation and Control

Prereq.: 9.35 or 9.62J, 18.02
U (1) **Next offered 1989-90**
3-0-6

Objects differ widely from each other as well as among themselves in terms of their appearance and behavior in a natural environment. These differences are limited, however, by the natural and physical properties of the world. Recognizing these constraints allows us to understand how different objects may be represented and manipulated. Examples stress the computation of visual aspects of a scene, although useful acoustic and tactile representations are also included.
W. A. Richards

9.362 Problems in Natural Computation (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
4-0-8

General survey of the field of natural computation is provided by 9.36 lectures, which students are expected to attend and complete. This basic material is supplemented by readings and in-depth study of a particular problem. Term paper required.
W. A. Richards

9.363 Research in Natural Computation (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Closely supervised research on a problem of inferring a property of the world, given only limited sensory data. Problems may be chosen from the fields of vision, audition, or force sensing (touch). The use of constraint in the inference process is stressed, as well as the exclusion of false inferences.
W. A. Richards

9.365 Dissection by Psychophysics (A)

Prereq.: 9.35 or Permission of Instructor
G (1) **Not to be offered 1989-90**
3-0-6

Noninvasive techniques for analyzing the level of processing of information by the brain. Methods include those which isolate receptors, first and second neuronal levels, thalamus, mid-brain, and at least two cortical levels. Although major examples are visual, some consideration is given to auditory and somatosensory systems.
W. A. Richards

9.366J Computer Graphics and Vision (A)

(Same subject as 4.904J)
Prereq.: 4.911 or 9.36
G (2)
3-3-6

The generation of realistic images requires knowledge of three areas: human visual processing, physical optics, and the power and limitations of graphics displays. Exploration of how these three areas interact in the design of realistic scenes and surfaces. Includes anti-aliasing, tiling, solid-modeling, shading, ray-tracing, color, texture, motion blur, and animation. Surfaces of particular interest are clouds, water, rocks (fractals), and trees.
W. A. Richards, A. Pentland

9.370 Computational Approaches to Motor Control (A)
(Revised Content and Unit)

Prereq.: —
G (2) **Not to be offered 1989-90**
3-0-9

Biological motor control viewed from the perspectives of robotics, systems theory, and artificial intelligence. Constraints on movement from the environment, mechanics, and physiology. Hierarchical planning levels: hand, joint, and muscle variables. Movement mechanics: inverse kinematics and redundancy resolution, inverse dynamics. Control of position and force. System identification, self-calibration, adaptation, and learning. Hand control: grasping, haptics, and tactile sensing. Computer simulation laboratory. Alternate years.
J. Hollerbach, C. Atkeson

9.371 Seminar in Computational Motor Control (A)
(New)

Prereq.: 9.370
G (1) **Next offered 1989-90**
3-0-6

Reading and discussion of selected current topics in computational motor control. Topics may be chosen from biological motor control, motor learning, motor psychology, biomechanics, robotics, or systems theory. The emphasis is on formulating mathematical bases for the control of movement, whether in biological systems or in machines. Alternate years.
J. Hollerbach, C. Atkeson

9.372 Movement: Mechanisms and Models (A)

Prereq.: 9.370, 9.373, or 9.374J
G (1, 2)
3-0-6

Research seminar directed at surveying basic concepts and methods in the study of the vertebrate motor system. Reviews current investigations on neural integration in movement control, emphasizing spinal cord, cerebellar, and cortical mechanisms; arm trajectory formation, physiology, and biomechanics; eye-head and eye-hand coordination; manipulation.
J. Hollerbach, E. Bizzi, C. Atkeson

9.373 Somatosensory and Motor Systems (A)
(New)

Prereq.: 9.014J
G (2) **Next offered 1989-90**
3-0-9

General principles of motor control in biological and artificial systems. Structure and function of sensory receptors. Muscle structure and reflex arcs. Spinal cord: descending and ascending pathways. Locomotion. Oculomotor control. Cerebellar structure and function. Motor thalamus. Basal ganglia. Somatosensory cortex: maps and neuronal properties. Motor psychophysics and computational approaches to motor control. Motor learning in biological and artificial systems. Alternate years.
C. Atkeson, E. Bizzi, M. Sur

9.374J Legged Locomotion in Robots and Animals (A)

(Same subject as 6.865J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 6.865J.
M. H. Raibert

9.375 Seminar in Hand Control and Tactile Sensing (A)
(New)

Prereq.: —
G (2) **Next offered 1989-90**
3-0-6

Readings and discussion of research on human hands and multi-fingered robot hands. Grasp planning, hand primitives, and basic grasping shapes. Control of grasping: stable grasp, fine motion control, and regrasping. Haptics: the hand as a sensory organ, inferring properties of objects through touch. Tactile sensing: properties of cutaneous receptors, continuum mechanics modeling, role of fingerprints. Robot hands: the Utah/MIT Dexterous Hand, the Stanford/JPL Hand, design of tactile sensors. Alternate years.
J. Hollerbach

9.38 Visual Information Processing: From Computational Theory to Neuronal Mechanisms

Prereq.: 9.01, 9.35, and 18.02
U (2)
3-0-6

9.380 Visual Information Processing: From Computational Theory to Neuronal Mechanisms (A)

Prereq.: —
G (2)
3-0-9

Study of biological vision from the perspectives of computation, psychophysics, neuroscience, and biophysics. Examines algorithms for solving vision problems; neuronal models of visual computations; the use of psychophysical and physiological data to test and modify computational models. Includes photometry, edge detection, motion, stereo, color, regularization theory, neuronal and biophysical mechanisms. Term paper required for graduate credit.
T. A. Poggio, E. C. Hildreth

9.382 Seminar on Visual Information Processing (A)

Prereq.: —
G (1, 2)
3-0-6

Discusses various computational problems in machine vision and biological vision. Topics: edge detection, stereo vision, analysis of time-varying images, surface interpolation, visual recognition, parallel algorithms, and hardware for computer vision. Centers around ongoing work by participants and presentations by them.
T. A. Poggio, E. C. Hildreth

9.39J Human Factors in Design

(Same subject as 2.18J, 22.088J)
Prereq.: Permission of Instructor
U (2)
3-1-8

See description under subject 2.18J.
A. Hein, T. B. Sheridan, D. D. Lanning

9.401 Survey of Cognitive Science

Prereq.: Permission of Instructor
G (1)
4-0-8

Survey of theories, methods, and findings in cognitive psychology and perception. Includes perception and psychophysics, pattern recognition, imagery and mental codes, memory and attention, and language comprehension and production. Permission of instructor is required.
M. C. Potter, R. Held, M. I. Jordan, D. Osherson, S. Pinker, K. Wexler, J. M. Wolfe

9.50 Research in Brain and Cognitive Sciences

Prereq.: 9.00 or 9.62J; and one other subject in Course IX
U (1, 2, S) LAB
2-8-2

Laboratory research in brain and cognitive science, using physiological, anatomical, pharmacological, developmental, behavioral, and computational methods. Each student carries out an experimental study under the direction of a member of the faculty. Project must be approved in advance by faculty supervisor and P. H. Schiller. Written presentation of results is required. Consult P. H. Schiller.

9.59 Psychology of Language and Communication

Prereq.: 9.62J or 24.900J
U (1) HASS
3-0-6

Studies real-time language processing. Systematic examination of core problems of language production and perception: lexical and syntactic processes in spoken and written language of both normal and language-impaired populations. Stresses methodological problems in psycholinguistic experimentation.
Staff

9.591 Seminar in Psychology of Language and Communication (A)

Prereq.: 9.59
G (2) **Next offered 1989-90**
3-0-6

Reads, discusses, and criticizes selected topics. Emphasizes one or more of the following themes in a particular term: theories of language, speech perception, communication in subhuman species, aphasia, language acquisition, language and thought, interaction between grammatical structure and verbal performance. Permission of instructor required for students without 9.59 or 9.901 background. Alternate years.
Staff

9.601J Language Acquisition (A)

(Same subject as 24.949J)
Prereq.: Permission of Instructor
G (1, 2) **Not to be offered 1989-90**
3-0-6

Reading and discussion of current theory and data concerning language acquisition. Emphasizes learning of syntax and morphology, and especially research relating syntactic theory and learnability theory to empirical studies of children's linguistic abilities. Alternate years.
Term 1: *K. Wexler*
Term 2: *S. Pinker*

9.605 Seminar on Visual-Spatial Cognition (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Reading and discussion on current theory and data relevant to cognition. Topics include visual information processing, attention, mental imagery, shape recognition, face recognition, reasoning, concepts, and language. Studies from experimental psychology, human neuropsychology, and artificial intelligence are discussed. Alternate years.
S. Pinker

9.62J Introduction to Cognitive Science

(Same subject as 24.116J)
Prereq.: —
U (1) HASS
3-0-9

Surveys major issues that occupy contemporary cognitive science. Topics: induction and inductive logics as psychological theories; formal learning theory in linguistics; Is English a finite state language?; deduction and deductive logics as psychological theories; concepts and conceptual composition; the problem of natural concepts; images and percepts. Emphasizes clear formulation of questions and theoretical criteria of adequacy. Examines specific proposals in response to these questions.
D. N. Osherson

9.621J Topics in Cognition (New)

(Same subject as 24.811J)
Prereq.: —
G (1)
3-0-9

See description under subject 24.811J.
J. Higginbotham, D. Osherson

9.63 Laboratory in Cognitive Science

Prereq.: 9.62J or 24.116J
U (2) LAB
0-6-6

Students conduct a set of demonstration experiments on human perception, memory, language comprehension, and imagery. These emphasize individual student solutions to design and analysis problems. In the final phase of the course, students perform an experiment of their own design on one of these topics. All experiments are run on-line in a computer-based lab. Enrollment limited.
S. Pinker

9.641 Connectionist Models of Cognitive Processes (A) (New)

Prereq.: —
G (2)
3-0-6

Study of representation, processing, and adaptation in highly interconnected networks of simple analog processing units. Explores basic algorithms as well as particular models of memory, speech perception and production, motor control, and language comprehension. Permission of instructor required.
M. I. Jordan

9.65 Cognitive Processes

Prereq.: —
U (2) HASS
3-0-6

An introduction to human information processing and learning; topics include the nature of mental representation and processing; the architecture of memory; pattern recognition; imagery and mental codes; concepts and prototypes; reasoning and problem solving.
M. C. Potter

9.651 Cognitive Processes (A) (New)

Prereq : 9.62J, 9.65, or equivalent
G (2) **Not to be offered 1989-90**
3-0-9

Surveys major issues and basic findings in human cognitive processing. Topics include pattern recognition, word perception, the architecture of memory, mental codes, learning, and attention, in addition to special topics of current interest. Alternate years.
M. C. Potter

9.66J Theory of Inductive Inference

(Same subject as 24.252J)
Prereq.: 9.62J
U (2)
3-0-9

9.661J Theory of Inductive Inference

(Same subject as 24.520J)
Prereq.: 9.62J
G (2)
3-0-9

Introduces the mathematical theory of inductive inference and learning. Applications to machine learning. Rigorous development of automata-theoretic models and general limitation results.
D. N. Osherson

9.671J Problems of Mental Representation (A)

(Same subject as 24.518J)
Prereq.: Three Philosophy subjects and Permission of Instructor
G (1)
3-0-9

See description under subject 24.518J.
G. Rey

9.68 Affect: Biological, Psychological, and Social Aspects of "Feelings"

Prereq.: 9.00
U (2) HASS
3-0-6

Affect is to cognition and behavior as feeling is to thinking and acting or as values are to beliefs and practices. 9.68 considers these relations — both at the psychological level of organization and in terms of their neurobiological and sociocultural counterparts.
S. L. Chorover

9.70 Social Psychology

Prereq.: —
U (2) HASS
3-0-6

Examines interpersonal and group dynamics, considers how the thoughts, feelings, and actions of individuals are influenced by (and influence) the beliefs, values, and practices of large and small groups. Learning occurs mainly through class discussions and participation in study groups. Regular homework assignments, occasional lectures, and demonstrations.
S. L. Chorover

9.75J Psychology of Gender

(Same subject as SP 460J)
Prereq.: —
U (2) HASS **Next offered 1989-90**
3-0-6

Examines evidence (and lack thereof) for differences in the ways men and women think, act, and feel; and in the ways their brains are organized. Topics: biological mechanisms of physical gender differentiation in mammals; male and female brain; sex differences in personality (aggression, capacity for intimacy) and in cognitive abilities (spatial and verbal skills); mechanisms of gender development (biological, psychoanalytic, social, cognitive); role of gender in differences in conceptualization of the world. Alternate years.
S. E. Carey

9.88 Origins of Behavior

Prereq.: 9.00 or 9.62J
U (2) HASS
3-0-6

Examines the evolving conceptualizations of infancy and early development. Considers the interaction of innate and experiential factors in the development of learning capacities, perception, motor patterns, and social interaction in animals and humans. Emphasis is on the earliest stages of life.
A. Hein

9.891 Seminar in Cognitive Development (A)

Prereq.: —
G (1) **Next offered 1989-90**
3-0-9

Surveys recent research in cognitive development. Topics include constraints on induction, knowledge representation and reorganization, cognition in infancy, semantic development, and conceptual change. Permission of instructor required. Alternate years.
S. E. Carey

9.91, 9.92 Topics in Brain and Cognitive Sciences

Prereq.: 9.00 or 9.62J and any other two subjects in Brain and Cognitive Sciences
U (1, 2)
Arr.

Individual research or study of a special topic under the direction of a member of the faculty. Consult S. E. Carey.

9.911-9.916 Special Topics in Brain and Cognitive Sciences (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Opportunity for graduate study of advanced subjects in Brain and Cognitive Sciences not included in other subject listings. Programs subject to approval of professor in charge. Consult M. C. Potter or W. G. Quinn.

9.921 Research in Brain and Cognitive Sciences (A)

Prereq.: —
G (1)
Arr.

9.922 Research in Brain and Cognitive Sciences (A)

Prereq.: —
G (2)
Arr.

9.923 Research in Brain and Cognitive Sciences (A)

Prereq.: —
G (S)
Arr.

Guided research under the sponsorship of individual members of the faculty. Ordinarily restricted to candidates for the doctoral degree in Course IX. Consult M. C. Potter or W. G. Quinn.

9.931 Research Reports (A)

Prereq.: —
G (1)
0-0-6

9.932 Research Reports (A)

Prereq.: —
G (2)
0-0-6

9.933 Research Reports (A)

Prereq.: —
G (S)
0-0-6

Graduate students submit written reports of their research efforts according to the Department's stated deadlines. Grade for this subject is the grade assigned by readers of the paper or committee members in the case of thesis proposals. Registration is mandatory for graduate students in fall term of second and third year and in term when thesis proposal is to be submitted. Restricted to candidates for doctoral degree in Course IX.
Consult M. C. Potter or W. G. Quinn.

Psychology

The undergraduate program in Psychology is described in Chapter 7. For additional related subjects in Psychology, see:
Architecture: 4.771

Brain and Cognitive Sciences: 9.00, 9.01, 9.06, 9.30, 9.35, 9.36, 9.351, 9.39J, 9.59, 9.62J, 9.63, 9.65, 9.68, 9.70, 9.75J, 9.88, 9.90

Management: 15.301, 15.304, 15.312, 15.313, 15.322, 15.339, 15.665, 15.824

Political Science: 17.704

Humanities: 21.386, 21.435

Science, Technology, and Society: STS 631, STS 635

Course 10 Chemical Engineering

10.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Opportunity for participation in the work of a research group, or for special investigation in a particular field. Topic and hours to fit individual requirements.
C. M. Mohr

10.ThU Undergraduate Thesis

Prereq.: —
U (1, 2, S)
Arr.

Program of undergraduate research, leading to the writing of an S.B. thesis; to be arranged by the student and appropriate MIT faculty member.
C. M. Mohr

10.001 Introduction to Computer Methods (New)

Prereq.: —
U (1)
2-0-4

Introduction to the use of computers in chemical engineering and to the computer environment on Athena. Exposure to methods for text and picture creation and manipulation, symbolic manipulation, and numerical programming. Elementary methods for numerical analysis are presented.
R. C. Armstrong, R. A. Brown

10.01 Engineering Concepts and Computer Methods

Prereq.: —
U (1)
2-8-2

Use of examples from chemical and biochemical engineering to convey concepts and methods. Simultaneously, students are introduced to the tools of an advanced computer environment on Athena. Examples include an overview of the chemical industries, balances and stoichiometry, rate phenomena and equilibria, synthesis and simulations. Computer tools used, among others, are text and picture creation and manipulation, symbolic manipulation, database management, and numerical programming.
L. B. Evans, M. A. Kramer

10.11 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

10.13 Chemical Engineering Thermodynamics I

Prereq.: *18.02*
U (1) SD
4-0-8

Basic concepts of thermodynamics. First, second, and third laws. Theoretical development with applications to open and closed systems. Concepts of energy, entropy, equilibrium, and reversibility. Introduction to properties of mixtures, including colligative properties, chemical reaction equilibrium, and phase equilibrium.
C. M. Mohr, K. Gleason

10.14 Chemical Engineering Thermodynamics II

Prereq.: 10.13
U (2)
3-0-6

Extension of 10.13, intended primarily for chemical engineering majors. Thermodynamics of multicomponent systems. Further discussion of the molecular basis of thermodynamics; quantum mechanical principles, spectroscopy, structure, and thermodynamic properties. Applications to open-system processes; power cycles, refrigeration, prime movers.
C. M. Mohr, T. A. Hatton

10.21 Structures and Properties of Matter

Prereq.: 5.11, 5.62
U (1) **Next offered 1989-90**
3-0-6

Atomic and molecular interactions and their importance in determining physical and chemical properties of matter. Dielectric properties of materials. Description of physical and specific chemical intermolecular forces, including hydrogen bonds. Bulk and interfacial properties of pure and mixed gases and liquids. Techniques for characterizing molecular structure and for predicting properties of matter.
C. K. Colton

10.25 Industrial Chemistry and Chemical Process Pathways (A)

Prereq.: 5.11, 10.14, 10.37
G (1)
3-0-6

Chemical and engineering principles involved in creation and operation of viable industrial processes. Topics: analysis of process chemistry by p-pathways (i.e., radical, ionic, and pericyclic reactions of organic syntheses) and d-pathways (i.e., catalysis by transition-metal complexes). Use of reaction mechanisms for inference of co-product formation, kinetics, and equilibria: process synthesis logic related to reaction selectivity, recycle, separations. Illustrations drawn from current and contemplated commercial practice.
P. S. Virk

10.26 Chemical Engineering Laboratory

Prereq.: 5.11, 10.14, 10.302, 10.37
U (1)
2-8-2

Laboratory projects in the areas of applied chemical research and unit operations. Students work in groups and choose one project for the whole term from projects suggested by local industry. Training in planning research projects, execution of experimental work, oral presentations and writing reports. Draws on all theory courses and literature surveys.
R. F. Baddour, D. J. Goldstein

10.27 Chemical Engineering Processes Laboratory

Prereq.: 10.13, 10.14, 10.301
U (2)
1-8-3

Introduces practical chemical engineering operations through hands-on experience with representative pilot-scale equipment and processes. Intended to provide instruction in the art of experimentation and data analysis and introduce theory of selected unit operations. Emphasis given to developing oral and written communication skills.
D. J. Goldstein, R. F. Baddour

10.28J Multivariable Control Systems I (A)

(Same subject as 2.154J, 6.233J, 13.481J, 16.341J)
Prereq.: 10.35 or 2.14 or 6.302 or 16.30
G (1)
4-0-8

See description under subject 6.233J.
G. Stephanopoulos, M. Athans, J. K. Hedrick, M. S. Triantafyllou, B. K. Walker

10.29J Multivariable Control Systems II (A)

(Same subject as 2.155J, 6.234J, 13.482J, 16.342J)
Prereq.: 10.28J
G (2)
4-0-8

See description under subject 6.234J.
G. Stephanopoulos, M. Athans, J. K. Hedrick, M. S. Triantafyllou, L. Valavani

10.301 Fluid Mechanics

Prereq.: 18.03
U (1, 2)
3-0-9

Introduces the mechanical principles governing fluid flow. Stress in a fluid. Conservation of mass and momentum, using differential and integral balances. Elementary constitutive equations. Hydrostatics. Exact solutions of the Navier-Stokes equations. Approximate solutions using control volume analysis. Mechanical energy balances and Bernoulli's equation. Dimensional analysis and dynamic similarity. Introduces boundary-layer theory and turbulence.
J. M. Beér, M. A. Kramer

10.302 Transport Processes

Prereq.: 10.13, 10.301
U (2)
4-0-8

Principles of heat and mass transfer. Steady and transient conduction and diffusion. Convective transport of heat and mass in both laminar and turbulent flows. Natural convection. Condensation and boiling. Application to design of heat exchangers. Radiative heat transfer.
G. Stephanopoulos

10.31 Separation Science

Prereq.: Permission of Instructor
G (1)
3-0-6

Advanced topics in separation science. Emphasis on characteristics and selection of separation processes, physicochemical aspects of molecular recognition and selectivity in separations, irreversible thermodynamics and generalized driving forces, coupling of driving forces and novel separations. Examples drawn from biotechnology, materials processing, and environmental control.
T. A. Hatton

10.32 Separation Processes

Prereq.: 10.14, 10.302
U (1, 2)
3-0-6

General principles of separation by equilibrium and rate processes. Staged cascades. Applications to distillation, absorption, adsorption, and membrane processes. Phase equilibria and role of diffusion.
C. M. Mohr

10.33 Analytical Treatment of Chemical Engineering Transport Processes (A)

Prereq.: 10.301, 18.02
G (1) **Next offered 1989-90**
3-0-6

Mathematical techniques underlying transport problems basic to most chemical engineering processes. Quaternions, vectors, polyadics, cartesian tensors, general tensors, curvilinear coordinate systems. Representations of rotation and orientation. Anisotropic material tensor properties. Applications to the derivation of transport equations in physical space, at interfaces, along lines, and in multidimensional phase spaces.
H. Brenner

10.331 Nonlinear Analysis in Chemical Engineering

Prereq.: 10.33
G (2)
3-0-6

Emphasizes both classical and modern methods for analyzing nonlinear ordinary and partial differential equations arising in reaction engineering and transport phenomena. Topics: elementary stability theory and bifurcation analysis of steady states; introduction to time-periodic phenomena and transitions to chaos; numerical methods for tracking multiple-steady and time-periodic states.
R. A. Brown

10.332 Linear Operator Theory in Chemical Engineering Science (New)

Prereq.: 18.03, 18.06, or equivalent
G (1)
3-0-6

Introduction to linear operator theory. Set theory, metric and linear spaces. Inner product and Hilbert spaces, orthogonality, adjoint and self-adjoint operators, spectral representation theory, Green's functions, and Sturm-Liouville operators. Applications to problems in partial differential equations and control theory.
T. A. Hatton, R. A. Brown

10.34 Numerical Methods Applied to Chemical Engineering (A)

Prereq.: 10.33
G (2) **Next offered 1989-90**
3-0-6

Numerical methods for solving problems arising in heat and mass transfer, fluid mechanics, and chemical reaction engineering. Topics: numerical linear algebra, solution of nonlinear algebraic equations and ordinary differential equations, and finite-difference and finite-element methods for elliptic and parabolic partial differential equations. All methods presented in context of problems arising in transport phenomena. Lectures and assignments assume knowledge of FORTRAN.
R. A. Brown

10.341 Finite Element Methods for Problems in Transport Phenomena (A)

Prereq.: 10.34
G (1)
3-0-6

Advanced methods for solving problems in fluid mechanics and heat and mass transfer. Emphasis on efficient techniques for handling highly irregular boundaries, nonlinearities, complicated boundary conditions, and singularities. Variational, Galerkin, and collocation schemes discussed.
R. A. Brown

10.35 Chemical Process Dynamics and Control (A)

Prereq.: 10.37, 18.03
G (2)
3-0-6

Introduces incentives and methods of chemical process control. Dynamic behavior of chemical reactors, separation units, heat exchangers. Model linearization and stability analysis. Design of simple PID controllers. Cascade, feedforward, and adaptive control. Introduction to multivariate control systems. Design of control systems for complete plants. Digital computer control.
M. A. Kramer

10.36 Process Design

Prereq.: 10.302, 10.32
U (2)
3-0-6

Presents an integrated approach to conception and preliminary design of chemical processing systems. It emphasizes invention of processing schemes, but it includes a balanced coverage of analysis and optimization. Case studies of real process design problems are used as a vehicle to illustrate problem-solving methodologies.
G. Stephanopoulos

10.361 Integrated Chemical Engineering I (New)

Prereq.: 10.32, 10.37, computer proficiency
U (1)
4-0-8

Presents and solves chemical engineering problems in industrial context. Emphasis is placed on the integration of fundamental concepts with approaches of process design. Problems are emphasized that demand synthesis, economic analysis, and process design.
G. Stephanopoulos, L. B. Evans

10.362 Integrated Chemical Engineering II (New)

Prereq.: 10.361
U (2)
4-0-8

Presents and solves chemical engineering problems in industrial context. Emphasis placed on integration of fundamentals with material property estimation, process control, product development, and computer simulation. Integration of societal issues, such as engineering ethics, environmental and safety considerations, and impact of technology on society are addressed in the context of case studies.
L. B. Evans, A. F. Sarofim

10.37 Chemical Kinetics and Reactor Design

Prereq.: 10.13, 10.301
U (2)
3-0-6

Introduces design of commercial chemical reactors, emphasizing synthesis of chemical kinetics, transport phenomena. Topics: kinetics and equilibrium — elementary steps, transition-state theory, multistep reactions and multiple paths, network algebra. Ideal reactors — batch, plug flow, well-stirred; residence-time distributions. Transport in reactors — heat and mass transfer, diffusion to and within catalyst particles. Reactor design — role of reaction pathway and thermochemistry; reactor size; modeling of performance.
P. S. Virk

10.38 Analysis and Simulation of Chemical Processing Systems (A)

Prereq.: 10.302, 18.03
G (2)
2-3-4

Techniques for computer-aided analysis of chemical processing systems. Development of mathematical models to describe dynamic and steady-state process behavior. Optimization techniques, numerical methods for solving resulting systems of nonlinear algebraic and differential equations and nonlinear programming problems. Students gain experience in solving case study problems on the computer.
L. B. Evans

10.381 Computer-Aided Process Design (A)

Prereq.: 10.302, 10.32
G (1)
2-0-7

Use of the computer for steady-state process simulation and design, with the aid of the ASPEN software system. Modeling the flowsheet, selection of thermophysical property models, use of data regression to fit constants in models, unit operation models, development of specialized models for chemical reactors, cost estimation, and economic evaluation. Techniques for convergence of recycle streams and design specifications. Students gain experience in the use of ASPEN to solve case study problems.
L. B. Evans

10.382 Synthesis and Design of Chemical Processing Systems (A)

Prereq.: 10.302, 10.32
G (1)
3-0-6

Unifying approach to synthesis and design of optimal process flowsheets. Selection of optimum chemical reaction route. Generation of alternative processing schemes and preliminary evaluation of process designs. Synthesis of optimal reactor networks, energy management systems, and separation sequences. Process design and its impact on process operability and controllability. Plant flexibility and resilience. Reliability analysis and design of safety systems for a chemical plant.
G. Stephanopoulos

10.39 Energy Technology (A)

Prereq.: 10.13, 10.14
G (2)
3-0-6

Studies the factors determining the choice of energy technologies and their individual design and performance features. Considers energy supply-demand patterns, economics, efficiency of resource utilization, and environmental and social effects. Gives special emphasis to synthetic fuel systems and utilization-related energy technologies. Special subjects such as fuel cells, solar energy, and geothermal energy can be studied and presented as term paper topics. Open to undergraduates.
J. B. Howard

10.40 Chemical Engineering Thermodynamics (A)

Prereq.: 10.13
G (1)
4-0-8

Basic postulates of classical thermodynamics. Application to transient open and closed systems. Criteria of stability and equilibria. Thermodynamic properties of pure materials and mixtures with some discussion of estimation and correlating techniques. Phase and chemical equilibria. Surface thermodynamics. Critical phenomena. Applications emphasized through extensive problem work relating to practical cases.
J. W. Tester, D. Blankschtein

10.42 Advanced Thermodynamics (A)

Prereq.: 10.40
G (2)
2-0-7

Equilibrium and stability concepts examined in depth for multicomponent, multiphase systems. Equations of state for pure components and mixtures, solution models for mixtures of electrolytes and non-electrolytes. Surface thermodynamics, equilibrium in body-force fields, statistical thermodynamics with Monte Carlo and molecular dynamics applications comprise other topics.
J. W. Tester

10.43 Introduction to Interfacial Phenomena (New)

Prereq.: 10.14 or an equivalent introductory course in thermodynamics or physical chemistry
G (2)
3-0-6

Introduces fundamental and applied aspects of interfacial phenomena. Theory of capillarity. Experimental determination of interfacial tension. Thermodynamics of interfaces. The Gibbs adsorption equation. The Van der Waals approach to interfacial phenomena. Surface tension of pure liquids and solutions. Surface films. Fundamentals of wetting and contact angles. Effect of curvature on the equilibrium state of pure systems and mixtures. Fundamentals of adsorption.
D. Blankschtein

10.49J Biomedical Transport Phenomena (A)

(Same subject as HST 521J)
Prereq.: 10.301, 10.302
G (2)
2-0-4

Applies the principles of transport phenomena to the analysis of selected physiological processes and the design of artificial internal organs and extracorporeal devices. Reviews pertinent physiological principles. Rheology of blood. Convective and diffusive mass transport in blood and tissues. Mass transport characteristics of biological and synthetic membrane processes. Artificial organs, including artificial kidney, pancreas, liver, and cardiopulmonary assist devices.
C. K. Colton, W. M. Deen

10.50 Analysis of Transport Phenomena (A)

Prereq.: 10.302
G (1, 2)
4-0-8

Analyzes diffusive and convective transport of heat and mass. Exact and approximate analytical solutions to steady-state and transient diffusion or conduction problems. Fundamentals of momentum transfer. Forced and free convection of heat and mass in laminar flow, including laminar boundary layers. Heat and mass transfer in turbulent flows. Simultaneous heat and mass transfer in problems with phase changes or chemical reactions.
R. C. Armstrong, R. A. Brown, W. M. Deen

10.51 Macromolecular Hydrodynamics (A)

Prereq.: 10.301
G (1) **Next offered 1989-90**
3-0-6

Observed phenomena in polymeric flow systems. Techniques of viscometry and viscoelastic measurements for polymeric fluids. Rheological models. Continuum theories. Molecular theories of polymeric fluids. Analytical solutions to flow problems; non-Newtonian viscosity, linear viscoelasticity, normal stresses, recoil, stress relaxation.
R. C. Armstrong

10.515 Structural Theories of Polymer Fluid Mechanics (A)

Prereq.: 10.301
G (1)
3-0-6

Structural and molecular models for polymeric liquids. Nonequilibrium properties are emphasized. Elementary kinetic theory of polymer solutions. General phase space kinetic for polymer melts and solutions. Network theories. Interrelations between structure and rheological properties.
R. C. Armstrong

10.52 Mechanics of Fluids (A)

Prereq.: 10.50
G (2)
3-0-6

Advanced course in fluid and continuum mechanics. Content may vary, drawing from such topics as low Reynolds number hydrodynamics, Brownian motion, suspension mechanics, flow in porous media, multiphase/particulate flow, ideal fluid theory, laminar boundary-layer theory, stability theory, and turbulence.
H. Brenner

10.53J Physicochemical Hydrodynamics (A)

(Same subject as 2.272J)
Prereq.: 10.50, 2.25
G (1)
3-0-9

See description under 2.272J.
R. F. Probstein, H. Brenner

10.54 Advanced Topics in Heat and Mass Transfer: Macrotransport Processes (A)

Prereq.: 10.50
G (2)
3-0-6

Generalized Taylor dispersion theory applied to chromatographic separation processes, flow in porous media, transport properties of macromolecular solutions, and generic analyses of heterogeneous systems, including adsorption phenomena and chemically reactive continua.
H. Brenner

10.55 Colloid and Surfactant Science (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

Introduction to theory and applications of colloidal dispersions and surfactant science. Monolayer adsorption at interfaces, electrical double layers, dispersion forces, electrokinetic phenomena, and stabilization of dispersions. Chemistry, structure, and classification of surfactants, critical micelle concentrations, micellar solubilization, and catalysis. Detergency and wetting phenomena. Emulsion technology and applications.
T. A. Hatton

10.56J Biotechnology of Mammalian Cells

(Same subject as 7.52J, 20.08J)
Prereq.: 7.03 or 7.05, 5.60 or 10.13
U (2)
4-0-8

See description under subject 7.52J.
A. J. Sinskey, D. I. C. Wang

10.565 Separation Processes for Biochemical Products (A)

Prereq.: —
G (1)
3-0-6

Introduces the fundamental problems of separation operations important to the recovery of products from biological processes. Biotechnology is placing new demands on chemical engineers to separate both large- and small-molecule weight molecules from aqueous media. Lectures cover membrane filtration, chromatography, centrifugation, electrochemical separation.
C. L. Cooney, C. K. Colton

10.57J Modeling of Biological Systems (A)

(Same subject as 20.802J)
Prereq.: Permission of Instructor
G (2)
2-0-7

Analytical (mathematical) descriptions of interesting biological mechanisms, systems, and processes. Examples covering the entire spectrum, from simple biological reactions to intricate networks of metabolic pathways, whole-cell metabolism, pure and mixed population dynamics and stability, and full bio-reactor models, considered. Emphasis focused on the accurate mathematical representation of biological reality and, hence, the correct problem definition for the purpose of organizing existing knowledge, enhancing system understanding, identification, and control.
G. Stephanopoulos, A. J. Sinskey

Biochemical Engineering

10.58 Structure, Dynamics, and Reactivity in Biotechnology

Prereq.: Permission of Instructor
G (1)
2-0-4

Overview of basic physical biochemistry of proteins and cells and interaction of biology and chemical engineering. Structure, function, and dynamics of biological macromolecules, emphasizing proteins. Prokaryotic and eukaryotic cell properties and relationship to cell function. Topics include protein stability, denaturation, motions and electrostatic properties; analytical techniques; cellular transport processes, and intercellular organization. Biophysical and biochemical phenomena considered, with an eye toward biotechnological processes.
M. L. Yarmush

10.59J Biochemical Engineering (A)

(Same subject as 20.811J)
Prereq.: Permission of Instructor
G (2)
4-0-8

Interaction of chemical engineering, biochemistry, and microbiology. Mathematical representations of microbial systems. Kinetics of growth, death, and metabolism. Continuous fermentation, agitation, mass transfer, and scale-up in fermentation systems, enzyme technology.
C. L. Cooney, D. I. C. Wang

10.591J Biochemical Engineering Laboratory (A)

(Same subject as 20.812J)
Prereq.: Permission of Instructor
G (2)
0-5-1

Laboratory portion of biochemical engineering. Experiments focus on mass transfer problems, microbial kinetics, product formation and recovery processes, and computer-aided fermentation. Fermentation process plant design. Permission of instructor required.
D. I. C. Wang, C. L. Cooney

Applied Chemistry

10.60 Heterogeneous Catalysis and Catalytic Processes (A)

Prereq.: 5.13 or 5.62
G (1)
3-0-6

An introduction to applied catalysis, focusing on principles of importance in the development and improvement of catalysts and their practical use in industry. Topics include adsorption phenomena, application of catalyst functionality concepts for control of reaction selectivity, kinetic models and correlation of rate data, poisoning and aging effects. Commonality of mechanisms for significant groups of catalyzed reactions such as hydrogenation, partial oxidation, and hydrocarbon reactions catalyzed by solid acids and zeolites. Recent industrial developments and projected future trends.
C. N. Satterfield

10.611J Microelectronics Processing Technology

(Same subject as 3.155J, 6.701J)
Prereq.: 6.071
U (1, 2)
3-4-5

See description under subject 6.701J.
H. H. Sawin, C. G. Sodini, D. J. Edell, D. A. Rudman, C. V. Thompson, K. Gleason

10.613 Solid-State Surface Science (A) (New)

Prereq.: 10.14
G (2)
3-0-6

Structural, chemical, and electronic properties of solids and solid surfaces. Analytical tools used to characterize surfaces including Auger and photoelectron spectroscopies and electron diffraction techniques. Surface thermodynamics and kinetics including adsorption-desorption, catalytic properties, and sputtering processes. Applications to microelectronics, optical materials, and catalysis.
H. Sawin, K. Gleason

10.616J Plasma Processing in Integrated Circuit Fabrication (A)

(Same subject as 6.776J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

See description under subject 6.776J.
H. H. Sawin, L. R. Reif

10.641J Thermal Transitions, Optical and Electrical Behavior of Polymers (A)

(Same subject as 3.93J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 3.93J.
R. E. Cohen, M. F. Rubner, P. Cebe

10.642 Molecular and Phenomenological Interpretation of Polymer Viscoelasticity (A)

Prereq.: —
G (1)
2-0-7

Theory and phenomenology of linear viscoelastic behavior of polymers. Material functions and their interconversion, model representation, time-temperature equivalence. Reviews molecular theories. Introduces nonlinear viscoelasticity.
R. E. Cohen

10.65 Chemical Reactor Engineering (A)

Prereq.: 10.37
G (1, 2)
3-0-6

Applies chemical kinetics to development and improvement of industrial processes. Nonideal reactor analysis, including residence-time distributions, concepts of mixedness, and segregation, dispersion, and CSTR models. Mass and energy transfer limitations in heterogeneous noncatalytic and catalytic reaction systems. Reactor stability and sensitivity to operating parameters. Choice and design of reactors for heterogeneous reactions.
J. B. Howard, A. F. Sarofim, C. N. Satterfield

10.651J Fluidization (A)

(Same subject as 2.65J)
Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

See description under subject 2.65J.
L. R. Glicksman

10.655 Multiphase Chemical Reactors (A)

Prereq.: 10.37
G (2)
3-0-6

Mass transfer with simultaneous chemical reaction in gas-solid, gas-liquid, and gas-liquid-solid systems. Analyzes contacting patterns and mass and heat effects in multiphase chemical reactors, including slurry-type reactors, trickle beds, and fluidized beds. Attention to reactions catalyzed heterogeneously or homogeneously, and to applications in fossil fuel processing and new synfuel processes.
C. N. Satterfield

10.66J Polymer Morphology and Properties Laboratory (A)

(Same subject as 3.97J)
Prereq.: Permission of Instructor
G (2)
1-5-6

Experimental methods for characterizing morphology and properties of polymeric fluids and solids. Microscopy of semicrystalline polymers and amorphous polymer blends. Thermal analysis. Mechanical testing. Rheological characterization. Students have the option to concentrate on rheological methods for entire term.
R. E. Cohen, D. K. Roylance, R. C. Armstrong

10.67 Polymer Science Laboratory (A)

Prereq.: Permission of Instructor
G (1, 2)
1-8-3

Synthesis and molecular characterization of polymers. Condensation polymerization and chain reaction polymerization and copolymerization, reactions in homogeneous phase and at interfaces, and the synthesis of linear chains and highly ramified structures are carried out. The resulting macromolecules are characterized: molecular mass and its distribution by several methods, composition and constitution by spectrometric and other analytical means, and molecular thermodynamic properties. Polymer-analogous reactions are used to modify macromolecules.
R. E. Cohen

10.681 Physical Chemistry of Polymers (A)

Prereq.: 5.60 or 10.14 or 10.40
G (1)
3-0-6

Chain conformation statistics. Elements of rubber elasticity theory. Statistical thermodynamics of the "liquid lattice." Applications to polymer-solvent and polymer-polymer miscibility, swelling of cross-linked polymers, melting point depression. Theory and methods of molecular weight determination (osmotic pressure, viscometry, light scattering, gel permeation chromatography). Response of isolated polymer chains to shear and extensional flows.
E. W. Merrill

10.682 Statistics of Macromolecular Systems

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Structure, configuration, and conformation of macromolecules. Polymerization and copolymerization statistics. Spatial arrangement of chains, linear and nonlinear, with and without the effects of excluded volume. Dilute and concentrated systems. Chain dynamics. Rotational isomeric state theory. Experimental observation of spatial arrangements of macromolecules, with special focus on scattering of radiation.
J. M. Deutch

10.691 Synthesis of Polymers (A)

Prereq.: 5.42
G (2)
3-0-6

Studies synthesis of polymeric materials, emphasizing interrelationships of chemical pathway, process conditions, and "microarchitecture" of molecules produced. Chemical pathway: anionic, radical, condensation, ring-opening. Process conditions: bulk, solution, emulsion, suspension, gas phase, batch vs continuous fluidized bed. "Microarchitecture": tacticity, molecular-weight distribution, sequence distributions in copolymers, "errors" in chains such as branches, head-to-head addition, peroxide incorporation.
E. W. Merrill

10.70 Principles of Combustion (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Basic concepts and applications of combustion: flame stabilization and propagation in gaseous fuel-oxidant mixtures. Turbulent jet flames. Swirling jet flames. Heterogeneous combustion: treatment of liquid fuel spray and pulverized coal. Advanced coal combustion technologies: fluidized bed, coal-water slurry, and slagging combustion. Mechanisms of pollutant formation and emission: oxides of nitrogen and sulfur, polycyclic aromatic compounds, fine inorganic particulates. Reduction of pollutant emission by combustion process modifications.
J. M. Beér

10.71J Air Pollution Control (A)

(Same subject as 2.29J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 2.29J.
A. F. Sarofim, J. A. Fay

10.72J Chemicals in the Environment: Sources and Control (A)

(Same subject as TPP 52J)
Prereq.: Permission of Instructor
G (1)
3-0-6

Sources and control technologies governing the emissions of chemicals into the environment. Material balance concepts and evaluation of ambient levels of chemicals in the environment. Evaluation of health and ecological impact. Concepts of risk assessment and management. Regulatory framework and historical background. Technological solutions based on process modification and emissions control. Case studies are selected from a range of major environmental problems ranging from hazardous waste chemicals, combustion-generated pollutants, acid rain, global CO_2.
J. R. Ehrenfeld, A. F. Sarofim

10.731 Seminar in Combustion Chemistry

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Readings, presentations, and discussions of selected, currently active research topics in combustion chemistry. One or two topics studied each term. Examples are chemistry and structure of flames, thermochemical kinetics methods and calculations, mathematical modeling and computer analysis of reaction networks, experimental methods, interactions of chemistry with transport and fluid mechanics.
J. B. Howard

10.732 Gas-Solid Reactions

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Review of current literature and research on gas-solid reactions, with particular emphasis on combustion, gasification, and gas absorption at high temperatures. Includes the mechanisms and kinetics of gas-solid reactions, the characterization of the structure and modeling of diffusion in porous solids, aerosol formation, and growth.
A. F. Sarofim, M. Flytzani-Stephanopoulos

10.74J Radiative Transfer (A)

(Same subject as 2.58J)
Prereq.: 10.302 or 2.51
G (2)
3-0-9

Principles of thermal radiations and their application to engineering heat transfer problems. Basic laws of thermal radiation. Radiative properties of surfaces. Radiant interchange among surfaces separated by a transparent medium. Thermal radiation characteristics of gases and particle clouds. Radiative interchange through absorbing, emitting, and scattering media. Application to furnaces, high-temperature processing, pyrometry, insulation, and solar energy.
A. F. Sarofim, L. R. Glicksman

10.75 Principles of Fuel Conversion (A)

Prereq.: 10.302, 10.37
G (2)
3-0-6

Basic features and classification of gasification and liquefaction processes applied to fossil fuels and biomass. Chemical and physical properties of natural and synthetic fuels. Kinetics, mechanisms, and products of pyrolysis of solid- and heavy-liquid fuels in presence of inert and reactive fluids. Thermodynamic and chemical equilibrium in multicomponent and multiphase C-H-O systems. Kinetics and mechanisms of gas reactions with solid carbon. Diffusion and reaction in porous solids with transient properties.
J. B. Howard

10.801 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
W. C. Flowers

10.805J Technology, Law, and the Working Environment (A)

(Same subject as TPP 35J)
Prereq.: —
G (1)
3-0-6

Addresses relationship between technology-related problems and the law applicable to work environment. National Labor Relations Act, Occupational Safety and Health Act. Toxic Substances Control Act, state worker's compensation, and suits by workers in the courts discussed. Problems related to occupational health and safety, collective bargaining as a mechanism for altering technology in the workplace, job alienation, productivity, and the organization of work addressed. Prior courses or experience in the environmental, public health, or law-related areas.
N. A. Ashford, C. Caldart

10.806 Management in Engineering

Prereq.: —
U (1)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult, H. S. Marcus

10.816 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

School of Chemical Engineering Practice

10.82 (10.80, 10.81, 10.83) School of Chemical Engineering Practice — Albany Station (A)

Prereq.: Permission of Instructor
G (1, 2, S)
0-12-0

Conducted at General Electric Company plants at their Noryl Plastics Division in Selkirk, NY, and Silicone Products Division in Waterford, NY. Group problem assignments conducted at plant sites involve development of existing polymer manufacturing processes. Exposure to highly diversified unit operations at pilot-scale or production levels, including distillation, extraction, filtration, extrusion, and fixed- and fluidized-bed reactor systems. Credit granted in lieu of Master's thesis; see Departmental description on School of Chemical Engineering Practice in Chapter 7 for details. Enrollment limited and subject to plant availability.
J. W. Tester

10.84 (10.85) School of Chemical Engineering Practice — Midland Station (A)

Prereq.: Permission of Instructor
G (1, 2, S)
0-12-0

Conducted at the research laboratories and manufacturing facilities of the Dow Chemical Company in Midland, MI. Group problem assignments include process development, design, simulation and control, technical service, and new-product development. Credit granted in lieu of Master's thesis; see Departmental description on School of Chemical Engineering Practice in Chapter 7 for details. Enrollment limited and subject to plant availability.
J. W. Tester

10.86 (10.87) School of Chemical Engineering Practice — Industrial Station (A)

Prereq.: Permission of Instructor
G (1, 2, S)
0-12-0

Conducted at the research laboratories and manufacturing facilities of a host company to be specified. Group problem assignments include process development design, simulation and control, technical service, and new-product development. Credit granted in lieu of Master's thesis; see Departmental description on School of Chemical Engineering Practice in Chapter 7 for details. Enrollment limited and subject to plant availability.
J. W. Tester

10.88 (10.89) School of Chemical Engineering Practice — Brookhaven or Los Alamos Station (A)

Prereq.: Permission of Instructor
G (S)
0-12-0

Conducted at either Brookhaven National Laboratory, Upton, NY, or Los Alamos National Laboratory, Los Alamos, NM. Group problem assignments, emphasizing application of chemical engineering to synthetic hydrocarbon fuels and alternate energy resources, electrochemistry, earth and environmental science, and nuclear technology. Credit granted in lieu of a Master's thesis; see Departmental description on School of Chemical Engineering Practice in Chapter 7 for details. Enrollment limited and subject to facility availability.
J. W. Tester

General

10.90 Experimental Research Problem (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

For special and graduate students who wish to carry out some minor investigation in a particular field. Subject and hours to fit individual requirements.
R. C. Armstrong

10.91 Experimental Research Problem

Prereq.: —
U (1, 2)
Arr.

For undergraduate students who wish to carry out a special investigation in a particular field. Topic and hours to fit individual requirements.
R. C. Armstrong

10.94 Special Problems in Chemical Engineering

Prereq.: Permission of Instructor
U (1, 2)
Arr.

Problem of current interest, varying from year to year.
R. A. Brown

10.95 Special Problems in Chemical Engineering (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Directed research and study of special chemical engineering problems.
R. C. Armstrong

10.971 Seminar in Fluid Mechanics and Transport Phenomena

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Seminar series on current research on Newtonian and non-Newtonian fluid mechanics and transport phenomena, and applications to materials processing. Seminars given by guest speakers and research students.
R. A. Brown, R. C. Armstrong

10.972 Biochemical Engineering Research Seminar

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Seminar allows students to present their research programs to other students and staff. The research topics include fermentation and enzyme technology, mammalian and animal cell cultivation, and biological product separation.
D. I. C. Wang, C. L. Cooney

10.973 Bioengineering

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Seminar covering topics related to current research in the application of chemical engineering principles to biomedical science and biotechnology.
C. K. Colton, W. M. Deen

10.974 Catalysis and Reaction Engineering

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Seminar on research topics and recent developments in heterogeneous catalysis, reaction engineering, and related topics. Intended primarily for students engaged in research in these areas, but open to students with background and interest in related areas such as surface sciences and noncatalytic reactions.
J. Wei, C. N. Satterfield, M. Flytzani-Stephanopoulos

10.975 Seminar in Polymer Science and Engineering (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Research seminars, presented by students engaged in thesis work in the field of polymers and by visiting lecturers from industry and academia.
R. E. Cohen, E. W. Merrill

10.976 Process Synthesis and Control

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Seminars in the state of the art in chemical process and control-system design, with emphasis on recent research. Discussions guided by the interests of participating students. Relevant topics in mathematics, numerical methods, and knowledge-based programming introduced.
M. A. Kramer, L. B. Evans

10.977 Artificial Intelligence in Chemical and Biochemical Engineering

Prereq.: Permission of Instructor
G (1, 2) [P/F]
3-0-3

Research seminars on the evolving state of the art in artificial intelligence, and how it affects the solution of problems in chemical and biochemical engineering. Includes expert systems in product and process development and design; learning expert systems in process control; expert assistants in problem formulation; model-based hybrid expert systems; search techniques; pattern recognition. LISP Programming, background in artificial intelligence necessary.
G. Stephanopoulos

10.978 Applied Thermodynamics and Applied Heat and Mass Transport

Prereq.: Permission of Instructor
G (1, 2) [P/F]
2-0-4

Review of current topics in applied and theoretical thermodynamics and transport. Subjects include micellar and microemulsion systems; enzyme kinetics; supercritical fluids and equations of state; phase equilibria in gas hydrate/clathrate systems; fundamental processes in multiphase contactors; and applied research problems involving heat and mass transfer in colloidal, biological, and geological systems.
J. W. Tester

10.979 Plasma Processing

Prereq.: Permission of Instructor
G (1, 2) [P/F] **Next offered 1989-90**
2-0-4

Advanced topics in plasma processing used in the fabrication of microelectronics. Emphasis placed on topics of plasma kinetics, gas-solid interactions, sputtering, and reactor design. Discussions include current research in the literature.
H. H. Sawin

10.980 Macrotransport Processes

Prereq.: Permission of Instructor
G (1, 2) [P/F] **Next offered 1989-90**
2-0-4

Seminar covering current research topics on theoretical aspects of transport processes, continuum mechanics, and statistical mechanics. Seminars given by graduate and postdoctoral students, participating faculty, and guest speakers.
H. Brenner

10.381 Seminar in Colloid and Interface Science (New)

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

Review of current topics in colloid and interface science. Topics include statistical mechanics and thermodynamics of micellar solutions and microemulsions; solubilization of simple ions, amino acids, and proteins in reversed micelles; enzymatic reactions in reversed micelles; phase equilibria in colloidal systems; interfacial phenomena in colloidal systems; biomedical aspects of colloidal systems.
D. Blankschtein, T. A. Hatton

10.982 Special Topics in Separation Science (New)

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

Selected topics are to be studied in depth to give a fundamental grounding for application to problems in separation science. Possible topics include electrodynamics and dielectric phenomena, irreversible thermodynamics, statistical mechanics.
T. A. Hatton

10.991 Seminar in Chemical Engineering (A)

Prereq.: Permission of Instructor
G (1) [P/F]
2-0-4

10.992 Seminar in Chemical Engineering (A)

Prereq.: Permission of Instructor
G (2) [P/F]
2-0-4

For students working on doctoral theses.
J. Wei

10.ThG Graduate Thesis (A)

Prereq.: —
G (1, 2, S,)
Arr.

Program of graduate research, leading to the writing of an S.M., Chem.E., Ph.D., or Sc.D. thesis; to be arranged by the student and appropriate MIT faculty member.
R. C. Armstrong

Course 11

Urban Studies and Planning

Undergraduate Subjects

Introductory Subjects

11.001 Introduction to Urban Design and Development

Prereq.: —
U (1)
3-0-9

Examines both the structure of the cities and ways that they can be changed. Includes historical forces that have produced cities, models of urban analysis, contemporary theory of urban design, and implementation strategies. A series of core lectures focuses on student work. Speakers present cases, involving current projects, which illustrate the scope and methods of urban design practice.
D. Frenchman

11.002 Introduction to Public Policy Analysis and Government Action

Prereq.: —
U (1) **Next offered 1989-90**
3-1-8

Presents major analytic techniques of public policy analysis: deterministic and probabilistic models, cost-benefit analysis, decision analysis, linear programming. Class sessions organized in order of main tasks of policy analyst: identifying alternatives, implementation, evaluation. Compares alternative approaches to public policy analysis.
G. T. Marx

11.003 Planning and Applied Social Research I

Prereq.: 11.007J, 14.01
U (1) **Next offered 1989-90**
4-0-8

Concerned with these questions: What theories from the social sciences are applicable to the design, implementation, or evaluation of public policies and programs? How good should such theories be? What theories of social science do current public policies and programs presume? How good are these theories? Same subject as 11.507. Consult: G. T. Marx.

11.005 Urban Social Structure and Process

Prereq.: —
U (2) HASS
3-0-6

Sociological analysis dealing primarily with transformations, from the turn of the century to the present, in the major institutions of urban society. Contemporary structures, changes, and interrelations of ecological and demographical bases; age and sex structures; stratification, economic, political, educational, and religious institutions. Examines ethnic and racial relationships in the US.
G. T. Marx

11.006J American Society: Values, Institutions, and Variety

(Same subject as 17.257J)
Prereq.: —
U (2) HUM-D
3-0-9

Study of American society, including the American value system and factors that shape it; the expression of these values in basic institutions such as government, work, religion, and family; sources of societal differentiation including class, gender, race, age, ethnicity, and region; and current and future social trends and scenarios.
G. T. Marx

11.007J Politics and Public Policy

(Same subject as 17.201J)
Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

See description under subject 17.201J.
G. T. Marx, M. Lipsky, E. M. Immergut

11.008J Economic Structure of Cities

(Same subject as 14.51J)
Prereq.: 14.01
U (1) HASS
3-0-6

See description under subject 14.51J.
W. Wheaton

11.013J American Urban History I

(Same subject as 21.412J)
Prereq.: —
U (1) HUM-D
3-0-6

Seminar on the history of institutions and institutional change in urban America from roughly 1890 to the present. Among the institutions considered are political machines, police departments, schools, courts, hospitals, prisons, welfare departments, and universities. Focuses on readings and discussions.
R. M. Fogelson

11.014J American Urban History II

(Same subject as 21.413J)
Prereq.: —
U (2) HUM-D
3-0-6

Seminar on the history of selected features of the physical environment of urban America. Among the features considered are parks, cemeteries, tenements, suburbs, zoos, skyscrapers, department stores, supermarkets, and factories.
R. M. Fogelson

Specialized Subjects

11.016 Introduction to Technology and Environmental Analysis

Prereq.: —
U (2) HASS
3-0-6

Comparative analysis of technological impacts on natural resources and the environment. Case studies of oil drilling, coal mining, power plant, dam, agricultural, automobile, and architectural impacts on national and global air, water, land, plant, and animal resources and marine environments. Analytic frameworks include natural science, economic, political, problem solving, and design approaches.
M. G. Klapp

11.017J Learning to Design and Designs for Learning (New — Context Subject)

(Same subject as 21.612J)
Prereq.: —
U (2)
3-6-3

How generalizable is design knowledge? How is it acquired? What are the elements, relations, exemplars, and representations that guide it? We build a culture of reflection on questions like these, starting with a few simple design tasks; then go on to designing in two specialized fields — mechanical structures and computer programming. On the basis of our experience in initial tasks and specialized areas, we examine similarities and differences in design processes across media and domains of expertise. May *not* count toward HASS requirement.
D. Schon, J. Bamberger

11.122 Environmental Policy and Regulation

Prereq.: —
U (1) HASS
3-0-6

See description under subject 11.361.
M. G. Klapp

11.131 The Urban Neighborhood

Prereq.: —
U (2) HASS
3-0-9

Covers theories, studies, and policy issues concerning the urban neighborhood, emphasizing the role of race and local involvement. Reviews neighborhood theory from the neighborhood unit to neighborhood territoriality; examines methods for studying neighborhoods, including research design and participant observation. Considers issues such as municipal decentralization, neighborhood abandonment, and maintaining public safety in the neighborhood.
J. M. D. Schuster

11.165 Law and Public Policy

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Examines how the legal system shapes, reviews, and implements public policy. Case examples drawn from environmental protection, school desegregation, abortion and insanity defense. Emphasis on procedural requirements to court, and the relationship of courts to other policy-making branches of government. Taught in the style of a first-year law course; students draft judicial opinions.
M. Wheeler

Laboratories

11.185J Design with Microclimate

(Same subject as 4.071J)
Prereq.: 8.01, 18.01
U (1) LAB
3-6-3

See description under subject 4.071J.
T. E. Johnson

11.188 Social Research Methods

Prereq.: Permission of Instructor
U (2) LAB
3-6-3

See description under subject 11.231. Required of all Course XI majors.
J. Ferreira, Jr.

Tutorials, Fieldwork, and Internships

11.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in Urban Studies and Planning. For further information, consult the Departmental Coordinators.
J. Ferreira, Jr.

11.191 Undergraduate Tutorial in Urban Studies

Prereq.: —
U (1)
3-0-6

11.192 Undergraduate Tutorial in Urban Studies

Prereq.: —
U (2)
3-0-6

Reading and discussion of special topics in urban studies. By arrangement with individual members of the staff.
G. T. Marx

11.193 Preparation for Undergraduate Thesis

Prereq.: —
U (1, 2) [P/F]
Arr.

Selects thesis subject, defines method of approach, and prepares preliminary thesis outline. Independent study, supplemented by frequent individual conference with staff members.
G. T. Marx

11.194 Special Topics in Urban Studies and Planning

Prereq.: —
U (1, 2)
Arr.

11.195 Special Topics in Urban Studies and Planning

Prereq.: —
U (1, 2)
Arr.

Small group study of special topics under staff supervision. For undergraduates wishing to pursue further study or fieldwork in specialized areas of urban studies or city and regional planning not covered in regular subjects of instruction.
G. T. Marx

11.196 Urban Fieldwork and Internships

Prereq.: —
U (1, 2) [P/F]
Arr.

Practical application of city and regional planning techniques to towns, cities, and regions, including problems of replanning, redevelopment, and renewal of existing communities. Includes internships, under staff supervision, in municipal and state agencies and departments under staff supervision.
G. T. Marx

Graduate Subjects

Core and Methods Subjects

11.200 Planning and Institutional Processes

Prereq.: Permission of Instructor
G (1)
3-0-9

Basic paradigms and theories of planning practice. Evaluates historical and current developments in planning, with special emphasis on the institutional setting of planning in American society. Lectures, case studies, and comparative analyses explore the changing roles of the planner and the key dilemmas in planning practice. Focuses on strategies of institutional intervention and implementation. Restricted to first-year M.C.P. students.
D. A. Schon

11.205 Planning Roles and Institutions in Developing Countries

Prereq.: —
G (1)
4-0-8

The planning process in developing countries. Interaction between planners and institutions at both national and local levels. Overview of theories of state, organizational arrangements, implementation mechanisms, and planning styles. Case studies of planning: decentralization, provision of low-cost housing, and new-town development. Analyzes various roles planners play in different institutional contexts. Professional ethics and values amidst conflicting demands.
B. Sanyal, R. Gakenheimer

11.206 Core Practicum

Prereq.: —
G (2) [P/F]
2-2-2

Small groups conduct in vivo planning exercises with a faculty advisor. Students engage in a project that raises pivotal issues in planning (values ideology, race/gender/class), and establish a group process that allows participants opportunity for reflection on group dynamics and self/roles in the context of planning. Restricted to first-year M.C.P. students.
T. Lee

11.210 Political Economy for Planners I

Prereq.: Permission of Instructor
G (1)
4-2-6

Introduces political economy for planners, emphasizing economic institutions and structural analysis of standard economic theory and public policy grounded in that theory. Models of individual economic behavior, institutional analysis of economic power, and Marxian political economy. Topics vary (e.g., poverty, race, gender, and class discrimination, changing urban form, industrial location). Restricted to first-year M.C.P. students.
K. R. Polenske, E. Meléndez

11.216 Writing for Public Policy and Planning

Prereq.: —
G (2)
2-0-4

Strategies for organizing and expressing ideas in writing. Students draft and redraft projects of their own choice, while sharpening their awareness of the writing process through exercise and feedback. Techniques for structuring analytical presentations, making use of intuition, anticipating reader response, and editing for academic or professional audiences. Limited to 15.
L. Dunlap

11.218 Fundamentals of Real Estate Financial Analysis

Prereq.: —
G (2)
2-0-4

Introduces financial feasibility analysis for real estate development and investment. Covers capital cost budget, pro forma, mortgage, tax shelter, valuation, and discounted cash flow analysis. Uses case problems to apply techniques to development of financial spreadsheet models. Integrates public- and private-sector financial issues.
L. B. Sagalyn

11.220 Quantitative Reasoning and Statistical Methods for Planning

Prereq.: Permission of Instructor
G (1)
4-2-6

Develops logical, empirically based arguments using statistical techniques and analytic methods. Covers elementary statistics, probability, and other types of quantitative reasoning useful for description; estimation, comparison, and explanation. Emphasizes the use and limitations of analytical techniques in planning practice. Restricted to first-year M.C.P. students.
J. M. D. Schuster

11.222 Decision Analysis for Planning

Prereq.: 11.220
G (2)
2-1-2

Analytical approaches to decision making and policy analysis when uncertainty is a central issue. Emphasizes decision trees, preference measurement, social choice problems, and determining an appropriate level of formal analysis. Includes analysis and critique of cases in planning and real estate development.
J. Ferreira, Jr.

11.223 Graphic Methods for Analysis

Prereq.: —
G (1)
2-1-1

Module covers four basic techniques of visualization: drawing, photography, video, and visual design in print. Provides planning students with a condensed introduction to visual communication techniques and the issues surrounding their use. Class sessions devoted to presentations, lectures, and instruction.
T. Lee

11.224 Impact Assessment Techniques (A)

Prereq.: 11.220
G (2)
3-0-6

Methods for predicting and evaluating impact of development, stressing predictive techniques for use by public officials without formal training in quantitative methods. Uses both computer-based modeling and non-quantitative techniques as aids in evaluation of alternatives. Includes traffic, fiscal, employment, and visual impacts.
P. B. Herr

11.226 Cost-Benefit Analysis for Planning

Prereq.: 11.220
G (1)
2-1-1

Module introduces students to the techniques of project analysis and to the strengths and weaknesses of cost-benefit analysis. Exercises provide practice in discounting, calculating rate of return, and calculating or applying shadow prices. Explores underlying rationales of various cost-benefit precepts and tools. Permission of instructor required.
A. M. Strout

11.227 Introduction to Computers in Public Management

Prereq.: 11.220
G (1, 2)
2-2-2

Meets concurrently with the first six weeks of 11.521. Topics: database management, spreadsheet analyses, and decision support systems. See description under subject 11.521.
J. Ferreira, Jr.

Intermediate Methods Subjects

11.230 Workshop in Institutional Analysis

Prereq.: 11.200
G (2)
4-0-8

Basic theories of institutional behavior, structure, and change for planners. Emphasizes institutions that directly affect the ability of planners to implement designs, policies, and development strategies. While students are expected to demonstrate ability to work with fundamental conceptual frameworks in institutional theory, primary focus is on application of institutional perspectives to practice-related issues.
D. A. Schon

11.233 Comparison and Lesson Drawing

Prereq.: —
G (1)
2-0-7

Focuses on issues in comparative policy analysis in housing and other areas by comparing experiences in developing and developed countries. Logic and method of comparison; review of policy studies; roles of setting and ideology in problem formulation; and lesson drawing for policy. Can be used to satisfy methods requirement.
M. Rein

11.235 Analyzing Projects and Organizations

Prereq.: —
G (2)
2-4-6

Seminar builds analytic skills in finding assumptions in what organizations say about themselves and transforming them into hypotheses for field evaluation: 1) using proxy indicators where data are poor and time is short; 2) preparing for, conducting, and interpreting interviews; 3) conducting cross-project and cross-organization comparisons; and 4) seeing the rationality in seemingly chaotic organizational and project environments. Desirable for students preparing for Master's or Ph.D. theses.
J. Tendler

11.236 Modeling for Development Planning

Prereq.: 11.210
G (1)
2-0-4

Techniques for macro and sectoral planning in developing countries: national and flow-of-funds accounts, input-output models based on such accounts, computer application.
L. Taylor

11.252 Legal Issues in the Development Process

Prereq.: Permission of Instructor
G (1)
3-0-9

Reviews land use law that provides the legal basis for regulation of the development process. Includes contracting law, alternative forms of property ownership, and secured interests.
L. Bacow

Environmental Planning and Design

11.301J Introduction to Urban Design and Development

(Same subject as 4.736J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Examines both the structure of cities and ways they can be changed. Includes historical forces that have produced cities, models of urban analysis, contemporary theories of urban design, implementation strategies. Core lectures supplemented by discussion group focusing on student work. Speakers present cases involving current projects illustrating the scope and methods of urban design practice.
D. Frenchman

11.320 Urban History Research Seminar

Prereq.: —
G (2)
3-0-6

Seminar for graduate students who wish to do research on the history of urban America in the 19th and 20th centuries. Each student is expected to write a research paper on a topic of his or her choice.
R. Fogelson

11.330J Theory of City Form (A)

(Same subject as 4.747J)
Prereq.: 4.736J or 11.301J
G (2)
Arr.

See description under subject 4.747J.
J. Beinart

11.332J Urban Design (A)

(Same subject as 4.163J)
Prereq.: Permission of Instructor
G (2)
Arr.

See description under subject 4.163J.
D. Frenchman

11.334 Environment Risk Assessment (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Examines use of risk assessment and risk management by regulatory agencies to set environmental standards and site hazardous facilities. Includes probabilistic risk assessment, decision analysis, sensitivity analysis, ecological modeling, risk control and bargaining, compensation, and risk perception. Cases include agency decisions on toxic chemicals and hazardous materials.
M. G. Klapp

11.335J Cities of Tomorrow (A)

(Same subject as 4.748J)
Prereq.: Permission of Instructor
G (2)
3-0-6

Research seminar on the future of urban design, to focus on developing a realistic projection of the organization, function, and form of cities, based on an analysis of contemporary trends. Review of historical efforts in the tradition of predicting urban change. Analysis of contemporary urban design projects and proposals. Supplemented by readings and speakers in parallel fields likely to have impact on urban form, including information processing, communications, entertainment.
D. Frenchman

11.336J Site Planning

(Same subject as 4.726J)
Prereq.: Permission of Instructor
G (1)
4-4-4

Considers the physical relationship of development to its site and context and includes methods of site evaluation, feasibility studies, site improvements, infrastructure requirements, and site planning techniques.
J. McKellar

11.337J Environmental Design Policy and Action (A)

(Same subject as 4.746J)
Prereq.: —
G (2)
3-0-6

Seminar on ways that governments influence the quality of environmental design. Focuses on the success and failure of methods for achieving urban design objectives through various public policy mechanisms: incentives, standards and regulations, owning and operating creation of legal rights, and information-based strategies. Students complete a research project.
J. de Monchaux, J. M. D. Schuster

11.338J Design Research Seminar (A)

(Same subject as 4.278J)
Prereq.: —
G (1, 2)
2-0-7

An exploration of the understandings and appreciative system implicit in design inquiry, through the examination of documented accounts of design processes. Includes design communication, language and notation, problem-framing and frame-reflection, roles of examples and metaphors in design, research programs in careers of master designers, cultural and institutional contexts of design, computational and models of designing.
D. A. Schon

11.360 Community Growth and Land Use Planning

Prereq.: —
G (1)
3-0-6

Seminar and fieldwork on strategies of planning and control for growth and land use, chiefly at the municipal level. Growth and its local consequences; land use planning approaches; implementation tools including innovative zoning, subdivision controls, infrastructure systems, and fiscal techniques. Projects arranged with small teams serving municipal clients.
P. B. Herr

11.361 Environmental Policy and Regulation

Prereq.: —
G (1)
3-0-6

Analyzes rationales for government intervention to protect the environment. Reviews policy instruments available to promote environmental quality, including standards, taxes, marketable rights, and liability rules. Same subject as 11.122.
M. G. Klapp

11.362 State and Federal Environmental Management (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Analyzes national, state, and regional efforts to plan for the allocation and use of environmental resources. Discussions focus on strengths and weaknesses of traditional planning and regulatory mechanisms. Political obstacles to plan implementation and strategies for citizens' participation in environmental policy making receive special attention. Students prepare in-depth case studies of reforms and management strategies.
L. E. Susskind

11.363J Chemicals in the Environment: Policy and Management

(Same subject as 15.650J, TPP 54J)
Prereq.: —
G (2)
3-0-6

Examines public policy questions concerning production and disposal of hazardous substances. Introduction to strategies for risk assessment, risk management, risk communication, and the privatization of regulation. Through case studies of standard setting, facility siting, and superfund cleanup efforts, students learn techniques of dispute resolution as they apply to hazardous substances policy and management.
L. Susskind, J. R. Ehrenfeld, J. D. Nyhart

11.364 Environmental Dispute Resolution

Prereq.: Permission of Instructor
G (2)
3-0-6

Introduces methods and formal theories of negotiation, mediation, and compensation as techniques to resolve environmental disputes. Examines ten current EPA cases involving rule making, permitting, and enforcement. Includes disputes over power plant siting, energy conversion from oil to coal and sewage treatment standards. Considers specific bargaining tactics and their strategic implications.
L. Susskind

11.365J Coastal Zone Management (A)

(Same subject as 13.98J)
Prereq.: Permission of Instructor
G (2)
3-3-6

See description under subject 13.98J.
J. T. Kildow

11.366 Comparative Environmental and Natural Resource Policies

Prereq.: —
G (2)
3-0-6

Comparative analysis of natural resource and environmental policies in advanced and less-developed countries. Cases include oil, natural gas, fisheries, water quality, acid rain, and port management. Analyses explain policy choices in terms of international and comparative national, political, and economic factors. Seminar format including student presentations.
M. G. Klapp

11.367 The Politics of Development (A)

Prereq.: —
G (2)
4-0-8

Analysis of the politics of development, particularly around site- specific cases. Emphasis on impacts of development on neighbors and others, interest-group politics, politics of public approvals, public-private partnerships, and training in negotiation skills. Surveys the broader politics of development on a state and Federal level, briefly examining the evolution of tax, transportation, and housing policies.
M. Wheeler

11.370 Theories of Settlement Patterns

Prereq.: —
G (2)
3-0-6

Examines locational theories and empirical evidence related to human settlement patterns and associated phenomena. Includes the spatial location of regional growth, size distribution of cities, migration patterns, area location of economic and noneconomic activities, and gravity modeling of spatial flows of goods and services. Requires an analytical term paper or empirical project.
A. M. Strout

11.380J Urban Transportation Planning (A)

(Same subject as 1.252J)
Prereq.: Permission of Instructor
G (1)
3-0-6

An issues course, with introductory lectures on urban transport planning process and technique. Structured writing and discussion on special concerns: 1) highway and transit finance needs, 2) roles for urban rail transit, 3) land development and economic renewal through transportation, 4) the prospects for privatization, 5) the problem of suburban freeway congestion, 6) the infrastucture finance shortfall.
R. A. Gakenheimer

Community and Regional Development

11.400 Community Development

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
2-0-7

Examines successful strategies and some theories of community development in the US. Through literature, guest lectures, and discussions, participants expected to synthesize their own strategies and intermediate-range theories.
F. S. Jones

11.410J Spatial Economics, Urban Markets, and Public Policy (A)

(Same subject as 14.573J, 1.283J)
Prereq.: 14.03J
G (1)
3-0-9

See description under subject 14.573J.
W. C. Wheaton, J. Rothenberg

11.411J Fiscal Federalism and the Local Public Sector (A)

(Same subject as 14.574J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 14.574J.
W. C. Wheaton

11.417J Planning in Socialist Countries (A)

(Same subject as 4.767J)
Prereq.: Permission of Instructor
G (2)
3-0-6

Introduces political economy of development strategies of the USSR, Eastern Europe, Yugoslavia, People's Republic of China, and Cuba. Examines significant debates leading to or emerging from experiences with three approaches to planning: administrative, indicative, and participative. Emphasizes links between physical, economic, and social planning, as well as between planning, design, and building. Requires participation in study groups.
T. Lee

11.420J Housing and Neighborhood Planning (A)

(Same subject as 4.743J)
Prereq.: 11.200 or 4.144
G (2)
4-0-8

Analysis of housing markets, consumption, investment, and policy. Techniques of neighborhood planning, including such issues as analysis of problem definition, program design, organizational issues, and strategic planning at the neighborhood level. Case studies of housing and neighborhood projects.
P. L. Clay

11.430J Introduction to the Development Industry

(Same subject as 4.721J)
Prereq.: —
G (1)
2-0-7

An understanding of the structure and operation of the development industry and some appreciation of the various actors that shape and influence the industry. Analyzes and evaluates steps in the development sequence and deals with terms, techniques, analytical methods and information sources required at each step. Deals with both the public and private sectors.
J. McKellar

11.431 Real Estate Finance and Investment (A)

Prereq.: 11.218
G (1)
4-3-8

Concepts and techniques for analyzing financial decisions in property development and investment processes. Includes pro forma analysis, equity valuation, discounted cash flow analysis, Federal tax analysis, debt and equity financing alternative, and an introduction to deal structuring. Considers both private- and public-sector perspectives.
L. Sagalyn

11.433 Market Analysis for Development Projects (A)

Prereq.: 14.01
G (2)
4-0-8

Focuses on developing an understanding of the factors that shape and influence markets for real property. Includes demographic analysis, patterns of regional growth, construction cycles, urban location theory, and modeling techniques for predicting demand.
W. C. Wheaton

11.434 Structuring Complex Real Estate Transactions (A)

Prereq.: 11.431, 11.252
G (2)
3-0-6

Case study analysis of financial and management structure of very complex real estate transactions. Focuses on allocation of risk and benefits among equity partners and lenders.
L. Bacow

11.435 Introduction to Economic Development Planning in the US (A)

Prereq.: 11.210 or 14.64 or 14.671 or 14.74
G (2)
3-0-6

Theoretical foundations of economic development processes in capitalist economies. Dependent development and internal colonialism. History of economic development policy in the US since the New Deal. Interregional/international conflicts over development policy. Critical assessment of plans for community economic development, city- or state-level programs, national policies for "reindustrialization."
B. Harrison

11.436 Labor Markets and the Organization of Work (A)

Prereq.: 11.210 or 14.01
G (1)
3-0-6

Neoclassical and Marxian economic theories of labor market structure: human capital, screening and credentialism, queueing, dual/segmented markets, labor theory of value, and occupational stratification by race and gender. Issues in measurement and policy evaluation. Development since the 19th century of theories about the changing organization of work (the "labor process").
B. Harrison

11.437 Financing Community Economic Development

Prereq.: —
G (2)
3-0-9

Examines role of capital in the economic development process, capital access problems of small, minority, and community-based businesses, and government options for overcoming these problems. Emphasizes role and operation of public-sector finance institutions. Presents and critiques case studies of interventions by development finance agencies. Student projects analyze either a specific intervention or the operation of a particular agency. Consult Department headquarters.

11.439 Methods of Downtown Development (A) (Revised Content)

Prereq.: —
G (2)
2-0-6

Focuses on public sector roles in stimulating and managing city development. Examines changing trends in public-private relationships, with specific cases drawn mostly from downtown projects. Analyzes interaction between government agencies and private developers in planning, financing, and implementing projects, with attention to political and economic factors.
B. J. Frieden, L. Sagalyn

11.441 Issues in Community Development

Prereq.: Permission of Instructor
G (1)
3-2-4

Centers on current issues in community development: values, ideology, tactics, models, and alternative strategies. Seminar format is organized around students' planning projects, and focuses primarily on problem framing from an interdisciplinary perspective. Designed for the Community Fellows Program; students working on thesis or community-based projects admitted by permission.
M. H. King

11.442 Strategies in Community Development

Prereq.: 11.441
G (2)
3-2-4

Continuation of 11.441. Focuses on alternative intervention strategies in community-based development. Seminar format is organized around students' planning projects, and centers on a review of relevant practice in the field, on formulation of both a detailed intervention strategy, project finding, and effectiveness evaluation plans. Designed for the Community Fellows Program; students working on thesis or community-based projects admitted by permission.
M. H. King

11.443 Cases in Community Development (A)

Prereq.: 11.400
G (2) **Next offered 1989-90**
2-5-2

Introduces students to a useful way of thinking about elements of community development, from the viewpoint of community activists and to the art of writing cases. Each student prepares at least one case and the appropriate briefing material, working with a client under supervision. Cases can be circulated for use by other students, teachers, and policy analysts.
F. S. Jones

11.444 Research Projects in Community Economic Development

Prereq.: —
G (1)
Arr.

Workshop on current issues in community economic development (employment, training, small business, CDCs, day care). Projects collaborate with one or several government agencies or community organizations. Students define a topic and conduct research within the general framework defined by the group. A report analyzing the problem and suggesting strategies and policies is presented to collaborating community organizations.
E. Meléndez

11.445 Community Development in Urban Neighborhoods

Prereq.: Permission of Instructor
G (2)
3-0-6

Politics of community-oriented economic development, focusing on oppressed groups in large cities. The problems of increasing political and economic power of ghetto residents. Consult M. H. King.

11.446 Political Economy of Race and Ethnicity

Prereq.: —
G (2)
3-0-9

Examines alternative views on political economy of race and race relations; history of colonization and oppression of people of color; political, economic, and social institutions reproducing inequality, and racial effects of public policies.
E. Meléndez

11.453 Seminar on Research in City Development and Housing (A)

Prereq.: —
G (1)
3-0-6

Advanced seminar for masters and doctoral students. Reading and analysis of monographs and reports that reflect current research issues in housing and city development. Class discussions of different types of research, the origins of ideas, implementation of programs, and evaluation. Each student designs and executes a piece of research that may include pre-thesis work.
B. J. Frieden, P. L. Clay

11.454 Innovations in Housing Policy

Prereq.: —
G (1)
2-0-7

Examines central issues in housing policy as currently debated and as they have emerged historically in the national, state, and local contexts. Provides the foundation for more detailed work in housing finance, production, market analysis, and policy development. Topics are low-income housing strategies; homelessness, special needs housing; homeownership, and public housing. Current efforts to develop a creative national housing policy for the post-Reagan era provide the "case study" for the elements under exploration.
L. C. Keyes

11.456 Thesis Preparation Seminar in Community and Regional Development (A)

Prereq.: Permission of Instructor
G (1)
2-0-7

For second-year M.C.P. students who are writing spring theses in community or regional development. Organized around interests and intended thesis inquiries of the students. Identifies methodological skills that seminar participants need to pursue their own work. Writing and mutual criticism of short concept papers, building toward a first-draft thesis outline by the end of term.
L. Dunlap, B. Harrison

Developing Areas

11.461 Planning and Urban and Regional Growth in Developing Countries (A)

Prereq.: 11.210
G (2)
Arr.

Examines ideas of planning in relation to urban growth issues and policy options. Covers problems of diagnosis and implementation of these policy options mainly in Third-World countries; and technical and political, national and sub-national, sectoral and intersectoral, and rural and urban aspects of these problems. Requires extended readings and paper.
B. Sanyal

11.462 Housing Problems, Goals, and Policies in Developing Countries

Prereq.: —
G (1) **Next offered 1989-90**
2-0-7

Focuses on how the definition of housing problems, requirements, and goals affect design and management of national policies and handling of issues related to land taxation, financing, building processes, self-help, tenure, and existing stock of housing. Concerned with price and subsidy policy and linkages between housing and national development strategies. Examined from several standpoints, including the paradigms of the mixed economy and of Marxism.
B. Sanyal

11.463J Structuring Low-Income Housing Projects in Developing Countries

(Same subject as 4.753J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 4.753J.
R. Goethert

11.464 The Informal Sector and the Household Economy

Prereq.: —
G (2)
3-0-9

Examines interrelationships among low-income households, small-scale, income-generating activities, and the urban economy in developing countries. Theories of employment and an analysis of "bazaar economies" looked at. Reviews policy options for enhancing the informal sector's contribution to development. The role of women and the possibilities of nonmonetary activities explored.
B. Sanyal

11.465J Special Interest Group in Urban Settlements: SIGUS Workshops (A)

(Same subject as 4.755J)
Prereq.: Permission of Instructor
G (2)
Arr.

See description under subject 4.755J.
R. Goethert, N. Hamdi, R. A. Gakenheimer, B. Sanyal

11.466 The Implementation of Metropolitan Planning in Developing Countries (Revised Content)

Prereq.: Permission of Instructor
G (2)
3-0-9

Techniques for implementing housing, land development, and other urban programs. Tools include regulation, financing methods, programming, design of organizations, use of "terms of reference." Cases of planning and decision making; roles of planning in implementation. Conducted jointly with Harvard Graduate School of Design.
R. Gakenheimer

11.469J Infrastructure in Third-World Countries (A)

(Same subject as 1.254J)
Prereq.: —
G (1)
3-0-9

Planning for transport, water supply, sewerage, etc. Summarizes the technologies but emphasizes the planning process and decision points within that are important to planned objectives. Deals with patterns of consumption, strategies of problems analysis, technology choices, equity questions, pricing, finance, building viable public-sector institutions, privatization, relationships between technocrats and politicians, roles of interest groups.
R. Gakenheimer

11.470 Political Economy of Development Projects

Prereq.: —
G (2)
3-0-9

Shows how performance of development projects and organizations is influenced by 1) nature of tasks they undertake, together with 2) structure of the economic environment; 3) political influence and actions of (or lack thereof) suppliers and other contractors, beneficiary groups, politicians; 4) contradictions between building strong organizations and pursuing certain development goals; and 5) behavior of donors and the constraints under which they operate.
J. Tendler

11.471 Political Economy of Development Projects: Targeting the Poor

Prereq.: —
G (1)
3-0-9

Covers impacts of various types of projects on income distribution; difficulties of assuring that project benefits reach the poor; types of projects, tasks, and environments that are conducive to equitable outcomes; roles of participation in helping organizations (including co-ops) to reach the poor and carry out projects more or less effectively; and the ability of nongovernmental organizations to "do better than the public sector" at serving the poor.
J. Tendler

11.481 Regional Economic Accounts, Theories, and Techniques (A)

Prereq.: 14.03, 14.04
G (2)
3-0-9

Surveys the basic accounting frameworks, theories, and techniques used in regional and multiregional economic analyses. Emphasizes the aspects of each relevant to their use in program impact and distribution studies. Uses problem sets (some microcomputer-based) to illustrate the different accounts, theories, and techniques.
K. R. Polenske

11.482 Regional Applications of Economic Theories (A)

Prereq.: 11.486J
G (1)
3-0-9

Critically examines the use of multiregional accounts and models for regional development analysis, including applications of economic base, regional growth, general equilibrium, and interregional trade models. Gives special attention to use of regional input-output models and to current regional analyses being made of transportation, energy, fiscal, income distribution, and employment problems.
K. R. Polenske

11.483 Theories of Political Economy and Planning for Developing Countries (A)

Prereq.: 11.486J
G (2)
3-0-9

Seminar covers major analytical frameworks of theories of political economy for developing countries, from both the neoclassical and Marxian perspectives. Key literature reviewed includes theories of growth, dualism, and psychological/cultural models, theories of imperialism, underdevelopment, dependency, and unequal exchange; growth pole, New International Economic Order, self-reliance, and basic-needs development strategies.
K. R. Polenske

11.484 Social Cost-Benefit Analysis of Projects and Programs

Prereq.: —
G (1)
3-3-6

Practical introduction to theory and practice of project analysis and evaluation. Develops quantitative skills through case study or practice. Problem-solving emphasis on cost and benefit valuation (both economic and noneconomic) and on considerations of time, space, scale, externalities, multiple-objectives, risk and uncertainty, and indirect benefits and costs. Examines usual institutional setting and practical influences of analytical procedures or project design and selection.
A. M. Strout

11.485 Rural Development: Agriculture and Industry in the Regional Context

Prereq.: —
G (2)
2-0-7

Role of nonmetropolitan, largely rural areas in regional development and problems of ensuring equitable improvements in rural welfare. Emphasizes agricultural growth, the transformation from a traditional to a modern agriculture, and the prospects for nonagricuitural pursuits in rural areas. Social and political as well as economic aspects of rural development. Considerable student participation, especially in working with case study materials from Africa, Latin America, Asia and, occasionally, from the US or Europe.
A. M. Strout

11.486J Theories of Economic Development

(Same subject as 14.778J)
Prereq.: *11.210*
G (1)
3-0-6

An overview of economists' theories of the development process: neoclassical, structuralist, and Marxist approaches. Includes national economic accounting and a sketch of planning models; long-run theories of growth and income distribution; short-run macroeconomics and stabilization; global macroeconomics, trade issues, and debt; technology and industrial strategy; agriculture and the food system; household economics, regional economics.
L. J. Taylor

11.487 Energy-Sector Planning in Developing Countries

Prereq.: —
G (1)
3-0-9

Evaluates relationship between energy and economic development. Includes analysis of energy demand, forecasting, and technology choice. Energy project planning and evaluation methods presented, and their relation to national planning discussed. Includes resource evaluation in gas, oil and solid fuels, energy pricing and taxation, electric power systems technologies, planning and economics, and economics and political roles of national and international agencies in energy planning.
R. D. Tabors

11.488J Politics, Technology, and Development in the Middle East(A)

(Same subject as 17.558J, 1.255J, 4.715J, 21.485J, STS 509J)
Prereq.: —
G (1)
3-0-9

See description under subject 17.558J.
N. Choucri, F. Moavenzadeh, K. Keniston, R. Lewcock

11.489J Technology, Development, and Public Policy in the Middle East (A)

(Same subject as 17.560J, 4.716J, 1.256J)
Prereq.: —
G (2)
3-0-9

See description under subject 17.560J.
N. Choucri, F. Moavenzadeh, W. Porter, P. Khoury, R. Lewcock, L. Trilling

Public Policy and Management

11.505 Seminar on Nonprofit Institutions and the City (A)

Prereq.: 11.200 or 11.230
G (2) **Next offered 1989-90**
2-0-7

Seminar on the nature and roles of nonprofit institutions. Emphasizes three themes: 1) the theory of nonprofit institutions (why is there a need for the third "sector" in addition to the private and public sectors?), 2) the relationships between nonprofit institutions and the state, and 3) issues in the management and operation of nonprofits. Topics vary each year. Students complete a major research project.
J. M. D. Schuster, M. Rein

11.507 Perspectives on the Labor Market

Prereq.: —
G (1)
2-0-7

Examines the different ways that the modern labor market has been transformed for women in the US and Europe. Reviews different approaches to understanding this transformation, focusing in particular on those theories that examine the interrelationship between the family, the state, and the labor market.
M. Rein

11.510 Discourse on Social Policy

Prereq.: —
G (2)
2-0-7

Examines discourse on controversial issues in policy making, mass media, social science, and public opinion. Probes for tacit framework of interests and assumptions that underlie discourse about controversial issues in each example. Each issue compares the content in two or more arenas, seeking generalizations that serve as the basis for analysis of discourse across arenas and issues.
M. Rein

11.515J Social Movements

(Same subject as 17.706J)
Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

See description under subject 17.706J.
G. T. Marx

11.517 Public Finance in Developing Countries (A)

Prereq.: 11.210
G (2) **Next offered 1989-90**
3-0-9

Financial operations of local and municipal governments/authorities in developing countries examined. Theories of taxation, public expenditure, and fiscal competition and comparisons of alternative fiscal systems explored. Evaluation of various policy options used in improving the management of services and revenue generation. Problems of local authorities looked at with an emphasis on current barriers and possibilities.
W. C. Wheaton

11.521 Computer-Based Analysis for Public Management I (A)

Prereq.: *11.220*
G (1)
3-2-7

11.522 Computer-Based Analysis for Public Management II (A)

Prereq.: 11.521
G (2)
3-2-7

Data-based, computer-implemented models for improving public management. Includes database management, decision support systems, scheduling, operations management, resource allocation, and spreadsheet analyses. Hands-on computer workshops to run models and analyze case studies. Required for urban management specialization.
J. Ferreira, Jr.

11.526J Logistical and Transportation Planning Methods (A)

(Same subject as 1.203J, 6.281J, 13.665J, 15.078J, 16.76J)
Prereq.: 6.431, 15.075
G (1)
3-0-9

See description under subject 1.203J.
A. I. Barnett, R. C. Larson, A. R. Odoni, H. N. Psaraftis

11.550 Bargaining, Negotiation, and Dispute Resolution in the Public Sector

Prereq.: 11.200, 11.230
G (1)
3-0-6

Investigates social conflict and organizations that process disputes in public sector. While theoretical aspects of conflict are considered, focus is on the operation, organization, and roles of dispute-processing agencies. Bases comparisons among agencies on their processes and consequences for participants and societies. Explores strategies for more effective design and use of dispute-processing agencies.
L. E. Susskind

11.551 Comparative Studies of Negotiation and Dispute Resolution (A)

Prereq.: 11.550 or Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

Advanced research seminar open only to qualified graduate students. Focus on cross-cultural and cross-group analysis of institutional barriers to effective dispute resolution. Students are expected to prepare detailed comparative case studies.
L. Susskind

11.552 Research Seminar on Theory-Building in Negotiation and Dispute Resolution (A)

Prereq.: 11.550 or Permission of Instructor
G (2)
3-0-6

Advanced research seminar open only to qualified graduate students. Focus is on cross-disciplinary contributions to the theory of negotiation and dispute resolution. Students are expected to prepare in-depth theory-building case studies. Special emphasis for 1989 is on the design of evaluation studies of practice.
L. Susskind

Doctoral Seminars

11.800 Doctoral Research Paper (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Analysis and practice in research competence fundamental to Urban Studies and Planning. Required of all first-year Ph.D. candidates.
L. C. Keyes

11.900 Doctoral Proseminars (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Designed primarily for advanced doctoral candidates. A selection of Proseminars is offered each year for groups of students affiliated with the various research clusters in the Department.
T. Lee

Tutorials, Research, and Fieldwork Subjects

11.901 Research Seminar: Topics in Urban Studies and Planning (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

11.902 Research Seminar: Topics in Urban Studies and Planning (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Special research issues in urban planning, selected each term for special study. Open to graduate students with permission of instructor.
T. Lee

11.911 Reading Seminar in Urban Studies and Planning (A)

Prereq.: Permission of Instructor
G (1) [P/F]
Arr.

11.912 Reading Seminar in Urban Studies and Planning (A)

Prereq.: Permission of Instructor
G (2) [P/F]
Arr.

Reading and discussion of special topics in urban studies and planning.
T. Lee

11.921, 11.922 Special Seminars in Real Estate Development (A)

Prereq.: —
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to real estate not otherwise included in the curriculum. Consult J. McKellar.

11.932 Preparation for Thesis (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

Selects thesis subject, defines method of approach, and prepares preliminary thesis outline. Independent study, supplemented by frequent individual conference with staff members. Restricted to doctoral candidates.
T. Lee

11.941-11.955 Special Studies in Urban Studies and Planning (A)

Prereq.: —
G (1, 2)
Arr.

Small-group study of advanced subjects under staff supervision. For graduate students wishing to pursue further study in advanced areas of urban studies and city and regional planning not covered in regular subjects of instruction. 11.941 is taught P/F.
T. Lee

11.962 Urban Fieldwork and Internships (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

Practical application of planning techniques to towns, cities, and regions, including problems of replanning, redevelopment, and renewal of existing communities. Includes internships, under staff supervision, in municipal and state agencies and departments.
T. Lee

11.981 Graduate Tutorial

Prereq.: —
G (1)
Arr.

11.982 Graduate Tutorial

Prereq.: —
G (2)
Arr.

Planned programs of individual instruction. Students and faculty members must make arrangements prior to the beginning of the term.
T. Lee

Course 12

Earth, Atmospheric, and Planetary Sciences

Undergraduate Subjects

12.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in Earth, Atmospheric, and Planetary Sciences. Consult T. H. Jordan.

12.ThU Undergraduate Thesis

Prereq.: —
U (1, 2)
Arr.

Program of undergraduate research, leading to the writing of a thesis; to be arranged by the student and an appropriate MIT faculty member. Consult J. B. Southard.

12.01 Introduction to Geology

Prereq.: —
U (2) SD
3-4-5

Major rock-forming minerals, rock-forming processes, and rock types. Geologic structures and relationships observable in the field. Geologic time scale, dating of rocks by fossil and radiometric methods. Movement of sediment and development of landforms by moving water, wind, and ice. Crustal processes and evolution in terms of global plate tectonics; surveys geologic history of the continents. Laboratory work on minerals, geologic mapping, and fossils. Two nonrequired weekend days of field trips.
J. B. Southard

12.010 The Surface of the Earth

Prereq.: 12.01
U (2) **Not to be offered 1989-90**
3-0-9

Water, wind, and ice, together with internal forces, shape the Earth's surface. Examines processes at work on and just below the surface — weathering, mass wasting, groundwater flow, rivers, glaciers, and the wind — and their consequences for the Earth's landscape and time scales of surficial change. Emphasis is on process and form, with consideration of people's interaction with surficial processes.
J. B. Southard

12.016 Sediments and Sedimentary Rocks

Prereq.: *12.01*
U (2)
2-2-5

Texture of clastic sediments. Sedimentary minerals. Petrology and classification of sandstones, shales, conglomerates. Modern carbonate depositional environments and sediments; petrology of ancient carbonates. Briefly treats other sedimentary rocks: chert, ironstone, evaporites, coal. Primary sedimentary structures. Lithification and diagenesis. Principles and techniques of interpreting ancient depositional environments. Laboratory work on petrology and classification of major rock types using hand specimens and thin sections. One weekend field trip.
J. B. Southard

12.017 Sedimentology in the Field

Prereq.: *12.016*
U (2) **Next offered 1989-90**
3-6-3

Introduction to techniques of sedimentologic and stratigraphic field work: examination and description of sedimentary rocks; description and measurement of stratigraphic sections; analysis of vertical succession of facies and lithologic units. Introductory classroom and laboratory work early in the semester, followed by intensive fieldwork during a part of spring vacation with subsequent data analysis and cooperative report preparation.
J. B. Southard

12.02 Chemistry and Physics of Minerals and Rocks

Prereq.: —
U (1) SD
3-4-5

Introduces geochemistry, mineralogy, and petrology. Properties of common rock-forming minerals: their crystal chemistry, structures, and stabilities. Evolution of igneous, sedimentary, and metamorphic rocks and of associated ore deposits. Laboratory work focuses on identification and paragenesis of the most significant minerals and rock types. Two field trips during laboratory classes.
R. G. Burns

12.03 Structural Geology

Prereq.: 12.01
U (1)
3-3-6

Introduces mechanics of rock deformations. Discusses and interprets faults, folds, structural features of igneous and metamorphic rocks, and superposed deformations. Introduces regional structural geology and tectonics. Laboratory includes techniques of structural analysis, recognition and interpretation of structures on geologic maps, and construction of interpretive cross sections.
B. C. Burchfiel, K. V. Hodges

12.051 Field Geology I

Prereq.: 12.02, *12.03*
U (1) **Next offered 1989-90**
2-2-2

Introduces techniques of geological field study. Several weekend field exercises provide practical experience in preparation for 12.052. Presents in addition some introductory material on the regional geology of the locale of 12.052.
B. C. Burchfiel, K. V. Hodges, L. H. Royden

12.052 Field Geology II

Prereq.: 12.051, 12.03
U (J, 2) **Next offered 1989-90**
Arr.

During January, practices methods of modern geological field study during an intensive four-week excursion. Exercises include geological mapping on topographic and photographic base maps, correlating geochemical and geophysical field measurements with geology, examining and sampling a wide variety of geological features. Following term includes 1) preparation of reports based on field studies conducted during January, and 2) laboratory analysis of samples, interpretation of geological, geophysical, and geochemical data.
B. C. Burchfiel, K. V. Hodges, L. H. Royden

12.061 Petrology I

Prereq.: 12.02
U (1)
3-6-6

Principles of optical mineralogy, emphasizing use of petrographic microscope for identification of minerals in rock-thin sections and mineral grain mounts. Introduces thermodynamics of heterogeneous-phase equilibria and its application to experimental and natural rock systems. Introduces experimental silicate systems. Surveys igneous rocks, emphasizing distribution, composition, mineral associations, origin, and relationship to tectonic environment.
T. L. Grove

12.062 Petrology II

Prereq.: 12.061
U (2)
3-6-3

Continuation of 12.061. Introduces mineral facies concept and graphical representation of metamorphic mineral associations. Petrographic examination of metamorphic rocks in thin section. Interpreting metamorphic rock paragenesis through application of experimental petrology to natural rock systems. Relationship of metamorphic rock associations to plate tectonic environment.
K. V. Hodges

12.066 Analysis of Geological Materials

Prereq.: 12.02
U (2) LAB
2-6-4

Determines the chemical composition of geologic materials. Analytical techniques include X-ray fluorescence, neutron activation, atomic absorption, mass spectrometry, electron microprobe, experimental petrology, Mössbauer, and other absorption spectral methods. Laboratory projects utilize these techniques to solve specific geologic problems. Limited to 12.
F. A. Frey, R. G. Burns, S. R. Hart, T. L. Grove

12.07 Chemistry and Physics of the Earth

Prereq.: 8.02, 18.03
U (1)
3-0-9

An integrated, problem-oriented introduction to the chemistry and physics of the solid Earth. Focuses on a series of major interdisciplinary problems in the areas of the internal constitution, dynamics, and evolution of the Earth; the geochemical and geophysical techniques appropriate for attacking each of these problems treated in this context. Topics include magma genesis and geophysical structure of mid-ocean ridges and island arcs; structure, composition, and dynamics of the mantle; and the evolution of the Earth's crust and mantle.
S. R. Hart, S. C. Solomon

12.091-12.094 Special Problems

Prereq.: —
U (1, 2)
Arr.

Reading, laboratory, or fieldwork in Earth, Atmospheric, and Planetary Sciences. Requires written report. 12.094 is taught P/F.
Staff

12.105 Introduction to Field Geophysics

Prereq.: 18.03
U (1) **Not to be offered 1989-90**
3-3-3

Introduces geophysical field techniques and instruments. Describes seismic, gravity, magnetic, and electrical methods and instruments. Some local field trips on weekends to test these techniques. For students with no experience in field geophysics.
T. R. Madden

12.106 Geophysics Field Study

Prereq.: 12.105
U (J, 2) **Not to be offered 1989-90**
Arr.

Applies geophysical field techniques and data interpretation to studying crustal structure and geological problems. Intensive four-week field measurements in snow-free area during January, and interpretation of data during spring term. Fieldwork includes seismic, gravity, magnetic and electrical measurements, and geologic studies. Data interpretation includes data reduction and computer modeling to determine structure and properties of the field area.
T. R. Madden

12.107 Introduction to Geophysics

Prereq.: 8.02, 18.03
U (1) SD
3-0-9

Survey course in geophysics aimed at earth science undergraduates or students from other departments interested in the applications of math and physics in studying the interior of the earth. Includes gravity (shape of the earth, isostasy, mass anomalies, precession), seismology (body waves, surface waves, earthquake sources, normal modes), geomagnetism (main field, secular variation, magnetic induction, rock magnetism), heat budget (radioactivity, heat flow, temperature structure), and geodynamics.
M. K. McNutt, T. H. Jordan

12.109 Fundamentals of Modern Geodesy

Prereq.: 8.01, 18.02, 18.06
U (1)
3-0-9

Coordinate systems and transformations used to describe the deformation and the rotation of the "solid" earth. Geodetic networks. Least-squares adjustment. Analysis of classical and modern types of observations. Emphasis on positioning by quasi-geometric techniques, including radio interferometry with satellite and quasistellar sources; lunar and artificial earth satellite laser ranging; terrestrial distance, angle and height measurements. Error causes and cures. Statistics, scientific computer programming background.
C. C. Counselman

12.113 Astronomy: Stars and Galaxies

Prereq.: —
U (1) SD
3-0-9

An introduction to stellar and galactic astronomy, emphasizing the underlying physical principles. Includes astronomical instruments; radiation laws and stellar spectra; physical properties of stars; stellar structure and evolution; supernovae, pulsars, neutron stars, and black holes; the interstellar medium; star clusters and galactic structure; galaxies and quasars; cosmology. Trips to Wallace Observatory.
L. M. French

12.114 Astronomy: Solar System

Prereq.: —
U (2) SD
3-0-6

Introduction to the study of the solar system. Emphasis directed toward basic principles rather than mathematical or physical details. Includes simple celestial mechanics, terminology of distances and magnitudes, optical properties of planets and satellites, planetary geology, interiors of the terrestrial and giant planets, magnetic fields, planetary atmospheres, comets and asteroids, solar physics and the formation of the solar system.
G. H. Pettengill, S. C. Solomon

12.117J Observational Techniques of Optical Astronomy

(Same subject as 8.287J)
Prereq.: One subject in Astronomy or Astrophysics
U (1) LAB
3-4-5

Fundamental physical and optical principles used for astronomical measurements at visible wavelengths and practical methods of astronomical observations. Topics: astronomical coordinates, time, geometrical optics, telescopes, photomultipliers and other detectors, photon counting, signal-to-noise ratios, limitations imposed by the earth's atmosphere on optical observations, photography, photometry, spectroscopy, and time variability. Project at Wallace Astrophysical Observatory.
J. L. Elliot

12.118 Project in Optical Astronomy

Prereq.: 12.117J or 8.287J
U (J, 2)
Arr.

Students select an observing project to be carried out at one of MIT's observatories or another facility, depending upon telescope and instrument scheduling constraints. Regular seminar meetings discuss the observations, data analysis, and interpretation of the results. Requires a written report on the project. Permission of instructor.
J. L. Elliot

12.126J Dynamical Astronomy

(12.133J)(Same subject as 8.293J)
Prereq. 18.03, 8.03
U (2) SD
3-0-9

Kepler's laws and the law of gravitation. One- and two-body motion; orbits in space and time. General and special cases of the n-body problem. Disturbed motion of two bodies; variation of orbital elements; planetary and satellite theory; periodic and secular effects; orbital resonance. Astronomical coordinate systems and time. Numerical integration of orbits. Maximum-likelihood estimation of orbital initial conditions and astronomical constants. Emphasizes throughout applications to actual problems, both historical and current, rather than on mathematical theory per se.
J. Wisdom

12.131J Planetary Science I

(Same subject as 8.291J)
Prereq.: 8.03, 18.03
U (1) SD
3-0-9

Study of the solar system with emphasis on the physical interpretation of its properties. Comprehensive overview of the solar system; accretion of the planets; solar system dynamics, with applications to planetary orbits and rings, terrestrial planets and gas giants, physics of comets, asteroids, and the interplanetary medium.
D. C. Jewitt

12.132J Planetary Science II

(Same subject as 8.292J)
Prereq.: 12.131J or 8.291J
U (2) SD **Next offered 1989-90**
3-0-9

Study of the solar system, with emphasis on the physical interpretation of its properties. Impact, volcanic, and other surface processes on planets and satellites; thermodynamics, convection, and magnetic fields in planetary interiors; dynamical, radiative, and chemical properties of planetary atmospheres.
D. C. Jewitt

12.151 Advanced Field Geology I (A)

Prereq.: 12.02, 12.03, 12.051, 12.052
G (1) **Not to be offered 1989-90**
2-2-2

Introduction to the problems to be investigated in 12.152, as well as the regional setting and local geology of the field area. Various special techniques may be introduced and preparatory investigations may be conducted that are specific to the area to be studied in 12.152.
B. C. Burchfiel, K. V. Hodges, L. H. Royden

12.152 Advanced Field Geology II (A)

Prereq.: 12.151
G (J, 2) **Not to be offered 1989-90**
Arr.

In January, a geological study of a selected field area is conducted during a four-week excursion. The following term includes 1) preparation of maps and report based on field study conducted in January, and 2) laboratory analysis of samples.
B. C. Burchfiel, K. V Hodges, L. H. Royden

12.20 Global Water Cycle

Prereq.: 5.03, 8.03
U (1)
2-0-4

Distribution of terrestrial water. Evaporation and rainfall; relationship to atmospheric circulation. Cloud and water vapor measured from ground, aircraft, and satellites. Water balance of continents and oceans. Droughts and floods; interaction with biosphere, including food production. Use of stable and radioactive isotopes to trace movement. Fossil water. Role in atmospheric energy budget. Precipitation as removal process for aerosols. Chemical weathering in the terrestrial environment. Factors controlling oceanic composition.
R. E. Newell, J. M. Edmond

12.21 Physics of the Ocean

Prereq.: 8.03, 18.03
U (2) SD
3-0-9

Introductory survey of oceanic circulation and dynamics. Descriptive aspects of water mass movement, currents, and physical properties of the ocean. Dynamic models of currents and waves based on fundamental physical principles.
P. Malanotte-Rizzoli

12.221-12.229 Project Studies in Oceanography

Prereq.: —
U (1, 2) [P/F]
Arr.

Extended participation in work of a research group, including independent study of the literature, direct involvement in group's research (commensurate with student's skills and preparation), or project work under an individual faculty member extending over more than one term. Admission by arrangement with individual MIT and Woods Hole faculty members.
Staff

12.23 Environmental Chemistry: Human Impact

Prereq.: 5.60 or 10.13
U (1)
3-0-9

Introduces the basic relevant principles and concepts in biogeochemistry, marine chemistry and physics, and atmospheric chemistry and physics through an examination of three current problems in environmental chemistry: 1) acid rain, 2) chlorofluorocarbons and ozone, and 3) carbon dioxide and climate. An introduction to environmental chemistry for students in basic sciences and engineering.
R. G. Prinn, E. A. Boyle

Graduate Subjects

12.ThG Graduate Thesis (A)

Prereq.: —
G (1, 2, S)
Arr.

Program of graduate research, leading to the writing of an S.M., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT faculty member. Consult T. H. Jordan.

12W.ThG Graduate Thesis (A)

Prereq.: —
G (1, 2, S)
Arr.

Program of graduate research, leading to the writing of an S.M., Ph.D., or Sc.D. thesis; to be arranged by the student and an appropriate MIT/WHOI faculty member. For students registered in MIT/WHOI Joint Program in Oceanography. Consult E. A. Boyle.

Geology and Geochemistry

12.301, 12.302 Seminar in Geology and Geochemistry (A)

Prereq.: 12.02
G (1) [P/F]
2-0-4

Fall seminar on topics of current interest in geology and geochemistry. Required background preparation for students taking predoctoral general examinations in these subjects.
S. R. Hart, Staff

12.311 Seminar in Regional Tectonics (A)

Prereq.: —
G (1, 2) [P/F]
3-0-6

Applies techniques of tectonic synthesis to study the roles of particular orogenic belts in global plate tectonics. Treats different applications in different terms, so that the subject may be taken repeatedly to learn the range of orogenic responses to temporal and spatial variations of activity at plate boundaries. Permission of instructor required.
B. C. Burchfiel

12.32 Mechanics of Sedimentary Processes (A)

Prereq.: 1.05 or Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Aspects of turbulent-flow mechanics relevant to sediment movement. Mechanics of sediment erosion, transportation, and deposition: modes of particle entrainment and motion in turbulent shear flows; sediment-bed configurations; erosion and deposition of cohesive sediments. Sediment gravity flows; sorting of sediments by particle size and density. Interpretation of primary structures and textures in modern and ancient sedimentary deposits on the basis of sediment-transportation mechanics.
J. B. Southard

12.33 Petroleum Geology

Prereq.: Permission of Instructor
G (1, 2) [P/F]
3-0-6

Origin, migration, and accumulation of petroleum. Geology of major oil-producing regions of the world. Geological and geophysical exploration techniques. Other topics of current interest. Taught by Crosby Visiting Professors. Consult Department headquarters.

12.34 Mineral Deposits

Prereq.: Permission of Instructor
G (1, 2)
3-0-6

Geological occurrence of the principal types of mineral deposits. Description of important examples in each category, together with examination of the ores. Modern hypotheses of origin of deposits and of metallogenic provinces. Discussion of relationships with plate margins. Taught by Crosby Visiting Professors. Consult Department headquarters.

12.35 Megascopic Strain Analysis in Orogenic Belts (A)

Prereq.: 12.03
G (1) **Not to be offered 1989-90**
3-0-6

Introduction to modern techniques used to estimate the magnitude of strain in orogenic belts. Emphasis on megascopic strain analysis. Includes 1) methods of determining sense of shear in various structural settings; 2) the construction of 2D-balanced structural sections; 3) the construction of 3D structural sections; and 4) graphical reconstruction of 2D and 3D sections to pre-deformational configurations.
K. V. Hodges

12.355 Seminar in Rock Mechanics (A)

Prereq.: —
G (1, 2) [P/F]
2-0-4

Discussion of current research or advanced topics in continental tectonics, rock mechanics, or experimental structural geology.
B. Evans

12.36 Sedimentary Basins (A)

Prereq.: 18.03, 12.03
G (1) **Not to be offered 1989-90**
3-0-6

Formation and evolution of basin systems in continental crust (including passive continental margins, foredeep accretionary basins, back-arc type basins, intra-plate rifts, etc.) are examined with regard to tectonic settings, structural and sedimentary features, and deep lithospheric processes. Case studies of several sedimentary basins of each type. Hydrocarbon maturation migration and accumulation is discussed in light of basin evolution processes.
L. H. Royden, J. P. Grotzinger

12.385-12.399 Special Problems in Geology-Geochemistry (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in geology, petrology, mineralogy or geochemistry. *L. H. Royden* (12.385); *K. V. Hodges* (12.386); *T. L. Grove* (12.387); *R. G. Burns* (12.388); *J. M. Edmond* (12.389); *F. A. Frey* (12.390); *C. J. Allegre* (12.392); *S. R. Hart* (12.393); *J. P. Grotzinger* (12.394); *B. C. Burchfiel* (12.395); *J. B. Southard* (12.396); *E. A. Boyle* (12.397); *Staff* (12.398, 12.399).

12.411 Isotope Geology (A)

Prereq.: 12.02
G (2) **Not to be offered 1989-90**
3-0-6

Applications of the variations in the relative abundance of radiogenic and stable isotopes to geologic problems. Topics: geochronology; studies of petrogenesis; geologic processes that can be traced by stable isotope fractionations, techniques, and instrument design.
S. R. Hart

12.42 Geochemistry of the Transition Elements (A)

Prereq.: 3.091, 12.02
G (2) **Next offered 1989-90**
3-0-9

Applications of resonance spectroscopic techniques to the study of energy levels and bonding of first-series transition elements in minerals. Theory and applications of Mössbauer, EPR, ESCA, and electronic absorption spectroscopy of minerals in the earth and planetary sciences.
R. G. Burns

12.43 Pressure-Temperature-Time Evolution of Orogenic Belts (A)

Prereq.: 3.01 or 5.60, 12.062, 18.03
G (1) **Next offered 1989-90**
3-0-6

Multidisciplinary introduction to modern techniques used to analyze burial and uplift histories of metamorphic terrains. Includes 1) geochronologic systems; 2) closure temperature theory and the use of geochronologic systems as thermochronometers; 3) geothermometry and geobarometry; 4) thermodynamic modeling of P-T paths; 5) thermal structure of orogenic belts, with emphasis on characteristic length scales and time scales for thermal events; 6) geophysical analysis of burial and uplift trajectories for metamorphic terrains.
K. V. Hodges, L. H. Royden

12.45 Trace-Element Geochemistry (A)

Prereq.: 12.07
G (1)
3-0-9

Studies element distribution in rocks and minerals using data obtained from natural and experimental systems. Emphasizes models describing trace-element partitioning and applications of trace-element geochemistry to problems in igneous geology.
F. A. Frey

12.46 Geochemical Kinetics (A)

Prereq.: 12.02
G (2) **Next offered 1989-90**
2-0-4

Basic principles of kinetics, both theoretical and phenomenological. Solutions of diffusion equation; reviews experimental data and techniques for silicate liquids and solids. Applications to natural geochemical systems.
S. R. Hart

12.48 Advanced Igneous Petrology (A)

Prereq.: 5.60 or 3.00
G (2) **Next offered 1989-90**
3-3-6

Thermodynamics, experimental phase equilibria, and kinetics combined to infer the physical conditions of igneous rock crystallization and magma production. Uses results of experimental studies to constrain processes that control magma genesis and give rise to the diversity of igneous rocks. Discusses theoretical approaches to thermometry-barometry techniques involving solid/solid and mineral/liquid reactions, kinetic controls on crystallization, and properties of silicate melts.
T. L. Grove

12.490-12.499 Advanced Seminar in Geology and Geochemistry (A)

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

Problems of current interest in geology and geochemistry. Subject matter varies from term to term. *Staff* (12.490); *T. L. Grove* (12.491); *R. G. Burns* (12.492); *F. A. Frey* (12.493); *S. R. Hart* (12.494); *K. V. Hodges* (12.495); *Staff* (12.496); *L. H. Royden* (12.497); *B. C. Burchfiel* (12.498); *J. B. Southard* (12.499).

Geophysics and Planetary Physics

12.501 Essentials of Geophysics (A)

Prereq.: 8.02, 18.03
G (1)
4-0-8

Overview of basic topics in solid-earth geophysics, such as the Earth's rotation, precessions and wobble, gravity and magnetic fields, seismology, and thermal structure. Formulation of physical principles presented in three 1-hour lectures per week. Current applications discussed in an additional 1 1/2 hour tutorial each week.
M. K. McNutt, T. H. Jordan

12.502 Plate Tectonics and Marine Geophysics (A)

Prereq.: 8.03, 18.075 or 18.085
G (2)
3-0-9

Introduces the formal theory of plate tectonics. Interpretation of magnetic anomalies and the age of the ocean floor. Thermal structure of the plates. Ocean floor depths and heat flow. Gravity anomalies. Crustal loading and lithospheric flexure. Crustal generation. Plate boundary stresses and mantle flow. Applies these ideas to the evolution of the ocean basins.
M. K. McNutt, J. Phipps-Morgan

12.512 Geoelectricity (A)

Prereq.: 8.03, 18.076 or 18.085
G (2) **Next offered 1989-90**
3-0-9

Electrical properties of earth's crust and mantle and application of electrical measurements to a variety of geological and geophysical problems, both practical and impractical. Subject matter includes electrical properties of porous media and high-temperature conduction in minerals. Applications include electrical and electromagnetic measurements to investigate rock types, mineral emplacements, fluid flows, earth strains, and mantle temperatures.
T. R. Madden

12.514 Geomagnetism (A)

Prereq.: 8.03, 18.076 or 18.085
G (2) **Not to be offered 1989-90**
3-0-9

Surveys magnetic and electromagnetic properties and processes in the earth's environment. Plasma environment of earth's magnetosphere and ionosphere and electromagnetic wave and particle phenomena occurring therein. Electric properties of the earth's interior. Magnetohydrodynamic origin of magnetic fields of earth and other astronomical bodies.
T. R. Madden

12.516 Reflection Seismology (A)

Prereq.: 12.107 or 12.521; 6.003 or 6.341 or 12.761 or 13.74J
G (2)
3-0-9

The use of reflection seismic techniques to image the earth's crust. Emphasis is on computational methods for processing and analyzing reflection seismic data. Includes discussions of seismic migration (integral, finite-difference, and Fourier methods), velocity estimation, near-surface corrections, inversion, deconvolution, stacking, and seismic interpretation. Principal text: J. F. Claerbout, *Imaging the Earth's Interior*.
D. H. Rothman

12.521 Elements of Seismology (A)

Prereq.: 18.075 or 18.085
G (1)
3-1-8

A basic subject in seismology and the utilization of seismic waves for the study of the earth's interior. Introduces techniques necessary for understanding of elastic wave propagation in layered media. Seismic-ray theory and interpretation of travel times. Surface-wave dispersion and layered media. Seismicity, earthquake magnitude, moment, and source properties.
M. N. Toksöz

12.522 Low-Frequency Seismology (A)

Prereq.: 8.06, 18.076
G (2) **Not to be offered 1989-90**
3-0-9

Seismological theory and methods based on the representation of the displacement field as a superposition of normal modes. Equations of motion; Rayleigh's Principle; perturbation theory; attenuation. Excitation formulae; the inverse problem of source structure. Traveling-wave representation; asymptotic expansions; surface and body waves. Free oscillations of a rotating, laterally heterogeneous earth; the inverse problem for 3D earth structure.
T. H. Jordan

12.523 Seismology Seminar (A)

Prereq.: 12.521
G (1, 2) [P/F]
2-0-6

An advanced reading and seminar subject on topics in seismology and closely related fields, involving critical analysis of current literature.
T. H. Jordan, D. H. Rothman, S. C. Solomon, M. N. Toksöz

12.524 High-Frequency Seismology (A)

Prereq.: 8.06, 18.076
G (2) **Next offered 1989-90**
3-0-9

Seismological theory and methods based on high-frequency approximations to transient displacement fields. Elastodynamic equations; representation theorems; moment-tensor representation; radiation patterns. Propagator and reflectivity methods; WKBJ and Langer approximations. Ray theory; Fermat's Principle; travel-time curves for spherically symmetric media. Radon transforms; inversion of travel times for earth structure; seismic tomography.
T. H. Jordan

12.525 Seminar in Computational Geophysics (A)

Prereq.: —
G (1)
2-0-4

Discussion of diverse computational problems in geophysics. Emphasis is on the modeling of geophysical phenomena and inversion of geophysical data. Topics may include, but are not limited to, estimation of earth properties from seismic data; seismic wave modeling; Monte Carlo methods; single-phase and multiphase fluid flow models; theoretical models in rock physics. A report on original research is required of each student. Permission of instructor required.
D. H. Rothman

12.53 Inverse Problems in Geophysics (A)

Prereq.: 18.075 or 18.085
G (1)
3-0-6

Problems of determining physical parameters of the earth's interior from surface observation of wave and potential fields. Iterative methods and linear analysis of parameter sensitivity and data-error effects. Stochastic models of parameter fluctuations. Exact inversion methods for one-dimensional problems. Migration and migration-like procedures for inversion.
T. R. Madden

12.534J Geophysical and Oceanographic Signal Processing II (A)

(Same subject as 6.456J, 13.742J)
Prereq.: 6.341 or 12.761 or 13.741J or 12.713
G (2) **Not to be offered 1989-90**
3-1-8

See description under subject 13.742J.
A. B. Baggeroer

12.54 Planetary Interiors (A)

Prereq.: 12.07, 18.075
G (2) **Next offered 1989-90**
3-0-9

Constitution, evolution, and structure of the interiors of the terrestrial and Jovian planets and of their satellites. Surface and integral properties of the planets and satellites. Gravitational fields and equilibrium configurations of planetary bodies. Equations of state of planet-forming materials. Internal structure of the planets and satellites. Planetary magnetic fields. Thermal evolution, convection, and their relation to surface tectonics.
S. C. Solomon

12.55 Properties of Rocks (A)

Prereq.: 8.03, 18.03
G (1)
3-0-9

Physical properties of rocks and their relation to cracks, pores, and minerals. Topics: elastic, transport, electrical, and magnetic properties; methods of measurement; and the factors that control each property. Applications to geotechnical engineering, borehole logging, geophysical exploration.
M. G. Simmons

12.57 Mechanical Properties of Rocks (A)

Prereq.: 8.03, 18.03
G (2)
3-0-9

A survey of the mechanical behavior of rocks in natural geologic situations. Topics: brief survey of field evidence of rock deformation, physics of plastic deformation in minerals, brittle fracture and sliding, and pressure-solution processes. Results of field petrologic and structural studies compared to data from experimental structural geology.
B. Evans

12.575 Geological Fluid Mechanics (A)

Prereq.: 8.03, 18.076 or 18.085
G (2) **Not to be offered 1989-90**
3-0-9

Treats heat transfer and fluid mechanics in the earth. Low Reynolds number flows, convection in stability, and double diffusion. Non-Newtonian flows, flow in porous media, and the interaction of flows with accreting and deforming boundaries. Applications include the flow under plates, postglacial rebound, diapirism, and the mantle convection problem.
(Woods Hole Staff): J. A. Whitehead

12.580-12.594 Seminar in Geophysics (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

Problems of current interest in geophysics; subject matter varying from term to term. *Staff* (12.580); *W. F. Brace* (12.581); *B. Evans* (12.582); *M. N. Toksöz* (12.583); *T. R. Madden* (12.584); *M. G. Simmons* (12.585); *M. K. McNutt* (12.586); *J. Phipps-Morgan* (12.587); *S. C. Solomon* (12.588); *D. H. Rothman* (12.589); *T. H. Jordan* (12.590); *Staff* (12.591, 12.592, 12.593, 12.594)

12.600-12.614 Special Problems in Geophysics (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in geophysics. *Staff* (12.600); *B. Evans* (12.601); *M. N. Toksöz* (12.602); *S. C. Solomon* (12.603); *T. R. Madden* (12.604); *M. G. Simmons* (12.605); *M. K. McNutt* (12.606); *J. Phipps-Morgan* (12.607); *W. F. Brace* (12.608); *D. H. Rothman* (12.609); *T. H. Jordan* (12.610); *Staff* (12.611, 12.612, 12.613, 12.614).

12.615 Solar System Dynamics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Modern overview of solar system dynamics, with emphasis on the qualitative behavior of the orbits and spins of the planets and their natural satellites, and the slow changes due to tidal interactions. Includes spin-orbit coupling of Mercury, chaotic tumbling of Hyperion, capture into resonance, chaotic behavior and the Kirkwood gaps in the asteroid belt, origin of meteorites, tidal dissipation and volcanism on Io, history of the lunar orbit, and stability of the solar system.
J. Wisdom

12.620J Radar Astronomy, Astrometry, and Geodesy (A)

(Same subject as 6.662J, 8.931J)
Prereq.: 6.014 or 8.03, 18.075 or 18.085
G (1) **Next offered 1989-90**
3-0-9

Applies techniques of radio and radar to measurement of the positions, orbital and rotational motions, surface and atmospheric characteristics, and gravity fields of the planets and satellites. Observations from spacecraft and from the ground. Propagation medium effects. Radar equation. Ambiguity resolution in active radar and in passive radio interferometry. Modulation, signal processing, detection, and analysis techniques. Radio-wave scattering. Uses of interferometry in radar mapping astrometry and geodesy.
G. H. Pettengill, C. C. Counselman, D. H. Staelin

12.633 Methods of Planetary Astronomy (A) (New)

Prereq.: Permission of Instructor
G (2)
3-0-9

The goal of this course is to prepare students (with previous observational experience) for carrying out their own observational programs. Topics covered: formulating an observing program; preparing a proposal for telescope time; capabilities of instruments and telescopes; techniques of data analysis, including astronomical image processing.
J. L. Elliot, D. C. Jewitt

12.660 Planetary Rings (A)

Prereq.: 12.131J or 8.291J, 18.075 or 18.085
G (2) **Next offered 1989-90**
3-0-9

Discussion of spacecraft and ground-based observations of the Jovian, Saturnian, and Uranian ring systems. Physical processes affecting their structure and evolution. Relations to satellites and theories of ring origin.
J. L. Elliot

12.662 Selected Topics in Planetary Science (A)

Prereq.: —
G (2)
3-0-9

In-depth discussion of current and classic literature on selected topics in planetary science. Seminar sessions where participants take turns leading class discussion on the readings. Topics vary from year to year. Permission of instructor required.
J. Wisdom

12.690 Topics in Planetary Science and Astronomy (A)

Prereq.: Permission of Instructor
G (1)
1-0-5

Discussion of diverse topics within the field of planetary science. Suitable subjects include, but are not limited to, results of recent, as well as plans for forthcoming, spacecraft missions to the planets; application of laboratory experiments to the study of the solar system; modern ground-based and *in-situ* investigations of comets; relation among recent astrophysical findings concerning the formation of stars and the planetary system.
D. C. Jewitt

12.691-12.699 Special Problems in Planetary Physics (A)

Prereq.: —
G (1, 2) [P/F]
Arr.

For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in planetary physics. *Staff* (12.691); *D. C. Jewitt* (12.692); *G. H. Pettengill*(12.693); *J. Wisdom* (12.694); *J. L. Elliot* (12.695); *C. C. Counselman* (12.696); *Staff* (12.697, 12.698, 12.699).

Meteorology and Oceanography

12.701 Marine Sediments (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

Sedimentary processes and interpretation of the depositional record in coastal environments, continental margins, and the deep ocean. Nearshore processes; sediments and structure of continental margins; deep ocean sediments (carbonates, clays, volcanogenic, authigenic); physical and acoustic properties of sediments; marine stratigraphy (excluding biostratigraphy); abyssal processes; and applications of marine sediments to paleoceanographic studies.
(Woods Hole Staff): W. Curry

12.702 Oceanic Volcanology and Petrology (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-2-4

Igneous processes occurring within and around the major ocean basins. Focuses on current observational data and hypotheses proposed to explain the observations. Discusses volcanic processes at spreading centers, tectonics, and vulcanism along fracture zones, island arcs, and subduction zones. Vulcanism and magmatic trends along linear island chains. Some practical training in data interpretation, petrography, and mineralogy may be arranged.
(Woods Hole Staff): W. Bryan

12.703 Marine Geology (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Designed to acquaint those with a background in geology and/or geophysics with the techniques used to study the processes responsible for the evolution, composition, structure, and morphology of the ocean floor. Includes techniques/instruments, with emphasis on multibeam sonar imagery and remote sensing, structure, and processes on passive/active continental and interoceanic margins and in ocean basins, tectonic evolution, mid-plate volcanism, deformation of sedimentary wedges at trenches, sedimentary processes, ocean paleoenvironment. Deep-sea drilling project.
(Woods Hole Staff): F. Uchupi

12.706 Fossils and Oceans: Biostratigraphy, Paleobiology, and Paleoceanography (A)

Prereq.: General and Historical Geology
G (1) **Next offered 1989-90**
3-2-7

The uses of microfossils in interpreting the geological history of the oceans and marginal seas. Major topics cover the nature and interpretation of the microfossil record, stratigraphic principles, geochronology, taphonomy and petrogenesis, systematics and species concepts, evolution, paleobiogeography, and paleoceanography. Associated labs treat the stratigraphic and evolutionary history of selected groups in foraminifera, calcereous nannofossils, radiolaria, and diatoms.
(Wood Hole Staff): W. Berggren

12.711 Marine Geophysics (A)

Prereq.: Permission of Instructor
G (1)
3-2-6

Introduction to theory and practice of marine geophysics. Overall purpose is to bridge the gap between geophysical method and geological understanding. Topics: measurements and geological modeling of marine magnetic anomalies, gravity, topography, heatflow, seismology, geochronology, and borehole logging. Laboratory sessions devoted to actual data. Extensive readings of geophysical literature.
(Woods Hole Staff): R. Stephen, R. von Herzen

12.712 Advanced Marine Seismology (A)

Prereq.: 12.711
G (1) **Not to be offered 1989-90**
3-0-6

Advanced course on theory and practice of marine seismology. Topics: seismic wave propagation; marine reflection and refraction seismology, including seismic data processing, modeling, and inversion of multichannel data. Extensive readings of geophysical literature.
(Woods Hole Staff): R. Stephen, M. Purdy

12.713 Topics in Geophysical Time-Series Analysis (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

Introduces selected aspects of geophysical time-series analysis, emphasizing step-by-step transformation of raw data to a usable format for statistical or dynamical modeling. Includes implementation of filtering techniques, Fourier transforms, sampling strategies, auto- and cross-spectra, data-adaptive techniques, and empirical orthogonal function analysis. Demonstrates application of these techniques to high-frequency geophysical phenomena common to the shallow marine shelf.
(Woods Hole Staff): D. Aubrey

12.720 Special Problems in Physical Oceanography at Woods Hole (A)

Prereq.: —
G (1, 2, S) [P/F]
Arr.

Reading, consultation, and original investigation on oceanographic problems.
(Woods Hole Staff)

12.721 Special Problems in Marine Geology and Geophysics at Woods Hole (A)

Prereq.: Permission of Instructor
G (1, 2, S) [P/F]
Arr.

For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in marine geology and geophysics.
(Woods Hole Staff)

12.722 Special Problems in Chemical Oceanography at Woods Hole (A)

Prereq.: Permission of Instructor
G (1, 2, S) [P/F]
Arr.

For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in chemical oceanography.
(Woods Hole Staff)

12.740 Paleoceanography (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

History of the earth-surface environment as deduced from the record in deep-sea sediments. Uses micropaleontological, isotopic, geochemical, and mineralogical changes observed in piston cores and ODP cores to infer changes in temperature and current field of the ocean and atmosphere, changes in seawater chemistry, and to evaluate and constrain theories of environmental change.
E. A. Boyle

12.741 Marine Geochemistry (A)

Prereq.: 5.11 or 3.091, 5.60
G (2) **Next offered 1989-90**
3-0-9

Composition of seawater: chemistry of aqueous solutions, ionic association and dissociation, and relevant calculations — concepts of steady-state and residence times of species and discussion of static vs dynamic chemical models of the ocean. Effect of oceanic circulation on the chemistry illustrated by the CO_2, silicate, and isotopic distributions. Discusses authigenic sediments, control of seawater composition, geochemical cycles. Emphasizes development of problems and topics by students and on calculations.
J. M. Edmond

12.742 Marine Chemistry (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Introduction to chemical processes operating in the oceans (i.e., biogeochemical cycles). Includes oceanic particles; cycling of organic carbon, P and nitrogen; carbonate and silica systems; upwelling and low-oxygen systems; iron and manganese redox systems. Designed for first- or second-year chemistry, biology, and geology students.
(Woods Hole Staff): E. Sholkovitz, O. Zafirou, M. Altabet

12.743 Geochemistry of Marine Sediments (A)

Prereq.: 5.11 or 3.091, 5.60
G (1) **Not to be offered 1989-90**
3-0-9

Chemical and isotopic composition of sediments in space and time. Present-day surface sediments. Equilibria and kinetics. Effect of sedimentary processes on the chemical composition of seawater. Dating and accumulation rate estimation. Oxygen and carbon isotope biostratigraphy. Effect of climate fluctuations on sedimentary processes. Emphasizes mathematical techniques and modeling where appropriate.
E. A. Boyle

12.744 Marine Isotope Chemistry (A)

Prereq.: 12.742 or 12.741
G (2) **Not to be offered 1989-90**
3-0-8

Treats important aspects of radionuclides and stable isotopes as applied to the oceans. Includes introduction to radio activity, natural-series radionuclides (i.e., ^{210}Pb, ^{210}Po, Th, U) artificial radionuclides (i.e. ^{14}C, ^{3}H, ^{137}Cs, ^{90}Sr, ^{239,240}Pu) and systematics of several stable isotopes (e.g., Nd, Sr, C, N, O).
(Woods Hole Staff): E. Sholkovitz, Staff

12.745 Ore Deposition at Submarine Ridge Axes (A)

Prereq.: —
G (1) **Not to be offered 1989-90**
3-0-6

Ridge crest hot springs; description of currently active systems. Geologic and tectonic setting and exploration strategies. Hydrothermal chemistry of sediment-starved and sediment-covered spreading centers and seamounts. Thermodynamic modeling of water-rock interactions using EQ3/6. Description and classification of ore deposits formed on the sea floor. Chemical and physical mechanisms of ore localization. Formation of metalliferous sediments. Permission of instructor.
J. M. Edmond, T. S. Bowers

12.746 Marine Organic Geochemistry (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

Includes air-sea interactions and atmospheric chemistry; sources, transport, transformation, and ultimate fate of organic materials in the sea, with an emphasis on specific organic compounds; biogeochemistry of pollutant organic compounds in the sea; origin of fossil fuels; stable isotope geochemistry applied to organic compounds; organometallic interactions; and marine natural-products chemistry.
(Woods Hole Staff): J. Farrington, D. Repeta

12.751-12.759 Seminar in Oceanography at Woods Hole (A)

Prereq.: —
G (1, 2)
Arr.

Topics in marine geology and geophysics, physical, dynamical, and chemical oceanography. Content varies from term to term. All but 12.755 are taught P/F.
(Woods Hole Staff)

12.762 Experimental Physical Oceanography (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Philosophy and design of physical experiments in the ocean. Review of dynamic and kinematic equations, scaling, and sampling theory. Description of previous experiments with regard to formulation of a hypothesis from a conceptual or theoretical model; translation of the hypothesis into an experimental design; and analysis of measurements.
(Woods Hole Staff): H. L. Bryden

12.763 Numerical Modeling in Oceanography (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

Introduction to numerical modeling techniques, with emphasis on oceanographic applications. Survey of standard methods for numerical approximation of partial differential equations, including explicit and implicit time-stepping, over-relaxation, stability analysis, sources of error, and the use of spectral (Galerkin) methods. Focus on applications to ocean modeling, including the implementation of general circulation and shelf models. Extensive "hands on" experience in applying techniques. Some background in FORTRAN programming required.
(Woods Hole Staff): D. Chapman

12.764 Laboratory Course in Geophysical Fluid Dynamics (A)

Prereq.: Permission of Instructor
G (2)
0-3-3

A substantial portion devoted to simple experiments that simulate large-scale geophysical flows and hence involve rotating or stratified fluids. Topics include properties of surface and internal waves, flow over topography, convection, and boundary layers. Aspects of smaller scale flows (low Reynolds number, surface tension, Langmuir cells) covered. The last third devoted to a student project.
(Woods Hole Staff): J. A. Whitehead

12.773 Air-Sea Interactions (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

Concentrates on methods, instruments, and recent results in the interaction of the atmosphere and the ocean on spatial scales less than 1,000 km and time scales less than seasonal. Topics emphasized are vertical fluxes of momentum, heat, and moisture over the ocean; mixed-layer development; and parameterization of ocean forcing by synoptic scale meteorology. Examples taken from recent experiments.
(Woods Hole Staff): R. Weller, J. Price

12.781 Dynamics of Shelf Circulation I (A)

Prereq.: 12.800
G (1) **Not to be offered 1989-90**
3-0-6

General introduction to the dynamics governing flow over the shelf. Transient response to wind forcing in closed basins and along open coasts. Simple effects due to stratification, topography, and to bottom friction as well as some aspects of thermocline circulation. Permission of the instructor required for students without 12.800 background.
(Woods Hole Staff): R. Beardsley, K. Brink

12.782 Dynamics of Shelf Circulation II (A)

Prereq.: 12.781
G (2) **Not to be offered 1989-90**
3-0-6

More specialized topics in the dynamics of flow over the shelf, including boundary-layer physics, tides, and coastal-trapped waves. Emphasis placed on the relationship between theory and observations and on the design and analysis of field experiments. Topics covered depend somewhat on the background and research interests of the students enrolled.
(Woods Hole Staff): K. Brink

12.790 Introduction to Observational Physical Oceanography (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

An introduction to the results and techniques of observations of the ocean in the context of its physical properties and dynamical constraints. Emphasis on large-scale steady circulation and the time-dependent processes that contribute to it. Includes the physical setting of the ocean, atmospheric forcing, application of conservation laws, description of wind-driven and thermohaline circulation, eddy processes, and interpretive techniques.
P. Malanotte-Rizzoli

12.791 Ocean Data and Ocean Models (A) (New)

Prereq.: 18.075 or 18.086
G (1) **Next offered 1989-90**
3-0-6

12.792 Ocean Data and Ocean Models (A) (New)

Prereq.: 12.791
G (2) **Next offered 1989-90**
3-0-6

Fundamental methods used for exploring the information content of observational data as they relate to theoretical ideas about how the ocean moves. Fundamental data processing methods including Fourier methods, basic statistics, spectra, coherences, z-transforms, sampling theorems, linear filters, etc., are covered in the first term. The second term is devoted to more advanced ideas including empirical orthogonal functions, singular value decomposition, regularization, inverse and control methods as applied to testing models, both analytical and numerical, against realistic, noisy, sparse observations.
C. Wunsch

12.795 The General Circulation of the Oceans (A)

Prereq.: 12.790 or Permission of Instructor
G (2)
3-0-6

A survey of the observational basis of the modern interpretations of global and regional ocean circulation. The material is predominantly focused on the large-scale low-frequency circulation, but mesoscale and fine-structure processes are included in connection with their impact on the larger-scale distributions. A mid-semester exam is given, and each student prepares a research proposal as

a term project. This project is the isolation of a general circulation issue, the planning of a field program to address the issue, and the putting together of a proposal in the form generally used with NSF or ONR.
(Woods Hole Staff): M. McCartney

12.800 Fluid Dynamics of the Atmosphere and Ocean (A)

Prereq.: 8.03, 18.04
G (1)
3-0-9

Introductory subject for first-year graduate students in meteorology and oceanography. Eulerian and Lagrangian kinematics. Equations of mass, momentum, and energy in Eulerian form in rotating frame of reference. Vorticity and divergence. Scaling and geostrophic approximation. Potential vorticity. Rossby waves. Ekman layers. Wave motion and instability. Thermal convection.
J. Pedlosky

12.801 Steady Circulation of the Ocean (A)

Prereq.: 12.800
G (2)
3-0-9

Fundamental principles in modeling steady flows in the ocean and their analogues in the atmosphere. Illustrates general methods that apply to either fluid and the contrasts between them. Includes quasi-geostrophy on the beta plane and sphere, Ekman pumping, Hadley/Ferrel circulations, wind- and thermally driven ocean circulation models. western-boundary current dynamics, upwelling systems.
R. Huang

12.802 Wave Motions in the Atmosphere and Oceans (A)

Prereq.: 18.350 or 12.800
G (2)
3-0-9

Wave motions in ocean and atmosphere. Energy flux, group velocity, dispersion, wave action. Shallow-water theory, internal waves, Rossby/planetary waves, equatorial waves, tides. Resonant interactions, wave-mean flow interaction. Discussion of observational base, with emphasis on the ocean.
D. Chapman

12.803 Theory of the General Circulation of the Ocean (A)

Prereq.: 12.800, 12.801, 12.802
G (2) **Not to be offered 1989-90**
2-0-4

A review of wind-driven, homogeneous, ocean circulation theory. Quasi-geostrophic scaling and the beta plane. Circulation on open and closed geostrophic contours in layer models. Potential vorticity homogenization. Western-boundary currents in a stratified ocean. Stommel-Arons theory for the abyssal circulation. Classical thermocline theory. The wind-driven, ventilated thermocline. The role of buoyancy forcing. Cross-gyre flow.
J. Pedlosky

12.804 Dynamics of the Atmosphere (A)

Prereq.: 12.800
G (2)
3-0-9

Review of equations of motion. Zonally averaged budgets of heat, momentum, and water vapor. Review of historical understanding of the maintenance of zonal winds. Symmetric models of the general circulation. Introduction to waves and eddies in nonrotating and rotating fluids: specifically internal gravity waves, tides, Rossby waves, barotropic and baroclinic instabilities. The interaction of these asymmetric components of atmospheric motion with the zonally averaged circulation discussed. Emphasis on specific observed phenomena.
R. S. Lindzen

12.805 Synoptic Scale Dynamics in the Atmosphere and Oceans (A)

Prereq.: 12.800, 12.801, 12.802
G (1)
3-0-9

Quasi-geostrophic equations for a stratified fluid on a sphere. Potential vorticity equation and low Rossby number. Available potential energy. Internal Rossby waves; the vertical structure equation and spin down. Planetary mountain waves and radiation of energy. Instability of currents in the atmosphere and oceans. Necessary conditions for instability. Baroclinic and barotropic instability. Energy cycles in the general circulations. Enstrophy and geostrophic turbulence.
G. R. Flierl

12.806 Instability and Turbulence in Geophysical Systems (A)

Prereq.: 12.805
G (2)
3-0-9

Comprehensive introduction to the methodology of stability theory as applied to problems of interest in geophysical fluid dynamics. Emphasizes problems governed by quasi-geostrophic dynamics. Topics in linear theory include baroclinic-barotropic instability, numerical methods for eigenvalue problems, Rossby wave instability, symmetric instability, and solution of initial-value problems. Nonlinear instability.
J. Pedlosky

12.809 Past and Present Climate

Prereq.: 8.03
U (2)
3-0-9

12.810 Past and Present Climate (A)

Prereq.: 8.03
G (2)
3-0-9

Properties of climate system. Climatic fluctuations on time scales up to 100,000 years. Phenomena of drought, biennial oscillation, Southern Oscillation and El Niño, and other interannual fluctuations. Role of volcanoes, carbon dioxide changes, and anthropogenic effects in altering climate. Reconstruction of ice-age climate from ocean-bed cores, pollen records, isotope ratios in ice cores. Theories of ice ages. Large-scale ocean-atmosphere interactions. Climate and agriculture. Suitable for undergraduate and graduate students with little or no previous background in meteorology.
R. E. Newell

12.811 Introduction to Meteorology

Prereq.: 8.02, 18.03
U (1)
3-3-6

12.812 Introduction to Meteorology (A)

Prereq.: 8.02, 18.03
G (1)
3-3-6

A broad introduction to atmospheric science for undergraduate and graduate students with no prior experience in meterology. Description and basic physics of atmospheric phenomena such as extratropical cyclones and anticyclones, hurricanes, thunderstorms, stationary waves and blocking, and the general circulation of the atmosphere. Laboratory studies acquaint the student with fundamentals of meteorological data analysis and forecasting. Development of elementary physical concepts such as hydrostatic and geostrophic balance, dry and moist thermodynamics, stability and instability, conservation of circulation, and vorticity and potential vorticity.
K. A. Emanuel, R. M. Dole

12.844 Synoptic Meteorology (A)

Prereq.: 12.811
G (2)
3-3-6

Planetary scale waves: structure and interpretation. Explanations of extratropical cyclones and anticyclones from polar-front theory to quasi-geostrophic theory. Fronts and frontogenesis. Cumulus convection and its interaction with larger scales of motion. Techniques for analyzing meteorological data.
R. M. Dole, K. A. Emanuel

12.846 Numerical Modeling in Meteorology and Oceanography (A)

Prereq.: 12.802
G (2)
3-0-9

Derives simplified sets of model equations, primarily by scale analysis. Discusses characteristics of atmospheric and oceanographic motions relevant to numerical analysis. Studies principal numerical methods used in geophysical fluid models. Consistency, convergence, linear and nonlinear stability. Data assimilation and the problem of meteorological noise. Draws examples from meteorology and oceanography, with emphasis on numerical weather prediction. Consult Department headquarters.

12.850 Physical Meteorology (A)

Prereq.: 5.60, 18.075 or 18.085
G (1)
3-0-9

Introduces atmospheric thermodynamics, physics, and chemistry. Thermodynamics of moist and dry air. Physics and chemistry of clouds and precipitation. Transfer of solar and thermal radiation through the atmosphere and radiative heating. Atmospheric electricity. Re-

mote sensing of atmospheric temperature, winds, precipitation, and composition by passive (e.g., infrared radiance) or active (e.g., radar) techniques.
R. G. Prinn, E. R. Williams

12.861 Topics in Waves and Instability (A)

Prereq.: 12.802 or 12.804, 12.805
G (1)
3-0-9

A detailed presentation of selected advanced topics in waves and instability in the atmosphere. Includes wave-mean flow interaction, the quasi-biennial oscillation, sudden warmings, critical-level behavior, wave overreflection, nonlinear equilibration, and wave breaking.
R. S. Lindzen

12.863 Diagnostic Studies of the General Circulation (A)

Prereq.: 12.801 or 12.802
G (1)
3-0-9

Description of diagnostic studies of atmospheric transports and energetics and discussion of their implications for the theory of the structure and general circulation of the atmosphere. Discusses the validation and use of numerical general circulation models as atmospheric analogs.
P. H. Stone, R. D. Rosen

12.864 Atmospheric Modeling (A)

Prereq.: 12.801 or 12.802, 12.850
G (2) **Next offered 1989-90**
3-0-9

Develops simple models for radiative heating, small-scale convection, and large-scale advection. Applies these models to comparative studies of planetary atmospheres and to climate problems.
P. H. Stone

12.865J Turbulence and Random Processes in Fluid Mechanics (A)

(Same subject as 16.044J)
Prereq.: 2.20 or *16.035*
G (1)
4-0-8

See description under subject 16.044J.
M. T Landahl, S. E. Widnall

12.866 Atmospheric Convection (A)

Prereq.: 12.800
G (2) **Not to be offered 1989-90**
3-0-9

Introduction and theory of dry convection over isolated heat sources. Basic theory of Rayleigh convection. Extensive treatment of the thermodynamics of moist and cloudy air. Observations and dynamics of isolated convective clouds; turbulence in saturated and partly saturated mixtures. Moist- and dry-convective boundary layers. Organization of moist convection on larger scales and interaction of convective ensembles with the large-scale environment.
K. A. Emanuel

12.875 Radar Meteorology (A)

Prereq.: —
G (2)
3-0-9

Principles of incoherent and coherent (Doppler) radar. EM scattering by precipitation particles. Signal fluctuations. Polarization-diversity techniques. Radar echoes from lightning. Multi-Doppler methods for observations of wind and particle motion fields. Applications to microburst detection in thunderstorms, cloud electrification, and streamflow prediction in hydrology. Permission of instructor required.
E. R. Williams

12.876 Measurements in the Atmosphere (A)

Prereq.: —
G (2)
3-0-9

Methods of observation in meteorology, emphasizing current research problems and conflicts between theory and experiment. Extraction of information from observations for comparison with theory. "Hands-on" experience in measurement techniques. Measurements in area of radar meteorology (precipitation, wind), atmospheric electricity (electric field, space charge, lightning), cloud microphysics (water vapor, ice crystals), atmospheric chemistry (trace gases), barometry (pressure, waves), radiation (temperature), and optics (rainbow, glory). Permission of instructor required.
E. R. Williams, R. G. Prinn.

12.950-12.959 Seminar in Physical Oceanography at MIT (A)

Prereq.: —
G (1, 2)
Arr.

Topics in marine geophysics, physical, dynamical, and chemical oceanography. Content varying from term to term. All but 12.950 are taught P/F.
Staff

12.960-12.969 Special Problems in Physical Oceanography at MIT (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

For graduate students desiring to perform special investigations, special laboratory work, or special fieldwork in oceanography. All but 12.965 are taught P/F.
Staff (12.960); *G. R. Flierl* (12.961); *P. Malanotte-Rizzoli* (12.962); *C. I. Wunsch* (12.963); *Staff* (12.964-12.969).

12.975J Principles and Physics of Remote Sensing in Oceanography (A)

(Same subject as 1.695J)
Prereq.: 1.60, 12.800
G (1) **Not to be offered 1989-90**
3-0-6

Propagation and sensing of EM waves and their interaction and scattering with the ocean's surface. Atmospheric absorption and scattering of microwave, visible, and infrared radiation. Celestial mechanics for understanding orbital dynamics and geometric distortions. Detailed survey of major instruments for measuring oceanographic variables from space. Emphasis on new methodologies, error assessment, and data interpretation.
(Woods Hole Staff): H. C. Graber, K. A. Kelly

12.976J Oceanographic Applications of Remote Sensing (A)

(Same subject as 1.696J)
Prereq.: 12.975J
G (2) **Not to be offered 1989-90**
0-3-6

Remote sensing principles learned in 12.975J applied to real data from GEOSAT, NOAA, and SEASAT satellites. Students required to analyze different types of data to determine calibration errors, instrument noise, spatial and temporal scales of the signal. The student selects one type of data for further examination of either the physics of the sensing process or relationship of the measured quantity to other oceanographic fields (term project). A working knowledge of computer programming is expected. Permission of instructor.
(Woods Hole Staff): H. C. Graber, K. A. Kelly

12.980-12.989 Special Problems in Meteorology (A)

Prereq.: —
G (1, 2)
Arr.

Reading, consultation, and original investigations on meteorological problems.
R. M. Dole (12.980); *K. A. Emanuel* (12.981); *J. C. Foster* (12.982); *R. S. Lindzen* (12.983); *R. A. Plumb* (12.984); *R. E. Newell* (12.985); *R. G. Prinn* (12.986); *P. H. Stone* (12.987); *P. Malanotte-Rizzoli* (12.988); *E. R. Williams* (12.989).

12.990-12.999 Special Subjects in Meteorology (A)

Prereq.: —
G (1, 2, S) [P/F]
Arr.

Organized lecture or laboratory subject on some aspect of meteorology not normally covered in the regularly scheduled subjects.
Staff

Course 13 Ocean Engineering

13.UR Undergraduate Research

Prereq.: —
U (1, 2, S) [P/F]
Arr.

Research in engineering for the ocean environment, including naval architecture, wave energy, seakeeping, ocean exploration, ocean transportation, ocean vehicles, utilization of resources, marine economics, systems analysis, marine policy, marine hydrodynamics, ocean acoustics, ocean structures, sailing yachts, and some aspects of marine-related management. Well-equipped and modern laboratory facilities.
D. K-P. Yue

13.00 Computer-Aided Hydrostatics and Hull Surface Definition

Prereq.: 8.01, 18.02
U (1) SD
3-3-6

Principles of hydrostatics with application to ships and floating offshore platforms. Static response to small disturbances, intact and damaged stability, floodable length. Mathematical representation of plane curves and surfaces by polynomials and spline functions. Computer graphical representation of three-dimensional shapes, including perspective transformations. Numerical integration and differentiation with application to hydrostatics. Homework projects include writing FORTRAN programs and using software developed under Project Athena.
J. E. Kerwin

13.003J Dynamics

(Same subject as 2.03J)
Prereq.: *2.01*, 2.02, 18.03
U (1, 2)
4-0-8

See description under subject 2.03J.
J. K. Vandiver, J. H. Williams, Jr.

13.012 Introduction to Naval Architecture

Prereq.: —
G (S)
5-5-11

Review/introduction to elementary principles of naval architecture, mechanics of solids, and fluid mechanics. Ship statics, fairing of lines, calculations, and drawing of displacement and other curves, structures, and ship resistance calculations. Applications to stress distributions and deformations in rods, shafts, beams, and other simple structures. Computer methods and matrix analysis utilized. Hydrostatics, vorticity, potential flows, boundary layers. Primarily for students in course XIII-A; others admitted by permission of instructor.
P. E. Sullivan, D. G. Karr, T. F. Ogilvie

13.021 Marine Hydrodynamics I

Prereq.: 1.05 or 2.20
U (1)
4-1-7

Develops hydrodynamic principles and their applications in the fields of ocean engineering and naval architecture. Model testing, viscous flows and boundary layers, potential flows, added-mass and lift forces, lifting surfaces, surface waves.
D. K-P. Yue

13.022 Marine Hydrodynamics II (A)

Prereq.: 13.021, 18.075
G (2)
4-0-8

Continuation of 13.021, emphasizing analytical methods. Laminar and turbulent boundary-layer theory. Ideal flows in two and three dimensions. Lifting-surface theory for steady, unsteady, and cavitating hydrofoils. Water waves, loads and motions of bodies in waves, and ship wave resistance. Hydrodynamics of slender bodies, maneuvering, strip theory of ship motions.
J. N. Newman

13.03 Wave Forces on Marine Structures (A)

Prereq.: 18.075, *13.022*
G (2)
3-0-6

Responses of ships and offshore platforms in waves. Linear-wave theory, added-mass, wave damping, exciting forces on floating bodies. Wave forces and motions of offshore platforms. Strip theory of ship motions. Newer theories. Ship-ship interactions in waves. Numerical solutions. Second-order wave effects. Steady-state drift forces. Ship added resistance in waves. Slowly varying wave forces. High-frequency excitation of tension-leg platforms. Ship springing. Projects with emphasis on applications using computer programs.
P. D. Sclavounos

13.04 Hydrofoils and Propellers (A)

Prereq.: 18.076, 13.021
G (2)
3-0-9

Theory and design of hydrofoil sections; lifting and thickness problems for sub-cavitating sections, unsteady flow problems. Computer-aided design of low drag, cavitation free sections. Lifting line and lifting surface theory with applications to hydrofoil craft, rudder, and control surface design. Propeller lifting line and lifting surface theory; computer-aided design of wake adapted propellers, unsteady propeller thrust and torque. Flow about axially symmetric bodies and low-aspect ratio lifting surfaces. Experimental projects in the variable pressure water tunnel.
J. E. Kerwin

13.06 Numerical Methods in Marine Hydrodynamics (A)

Prereq.: 13.021, 13.50, 18.075
G (2)
3-0-9

Formulation, methodology, and techniques of numerical solutions of potential flow problems. Rudiments of finite-difference, finite-element, boundary-integral-equation, and spectral methods with illustrations of applications to marine hydrodynamics. Emphasizes treatment of free-surface and open boundaries, characteristics and effectiveness of various approaches. Projects involve hands-on development of simple computer programs.
D. K-P. Yue

13.07 Free Surface Hydrodynamics (A)

Prereq.: 13.022; 18.076
G (1) **Next offered 1989-90**
3-0-6

Water wave phenomena pertinent to problems in naval architecture and ocean engineering. Generation, propagation, and diffraction of plane progressive waves. Exciting and restoring forces on floating and submerged bodies. Ship waves and wave resistance. Selected topics of interest in non-linear wave propagation, internal waves, slender-body theory, or seakeeping. Some background in water waves equivalent to that covered in 13.022 assumed. Alternates with 13.09.
J. N. Newman

13.09 Potential Flows (A)

Prereq.: 13.022; 18.076
G (1) **Not to be offered 1989-90**
3-0-6

Develops and applies potential theory to the flow past marine vehicles. Review of ideal fluid theory. Simple potential flows. Two-dimensional flows based on complex variable theory. Three-dimensional flows based on separation of variables and Green's theorem. Description of numerical methods, matched-asymptotic expansions, and slender-body theory. Hydrodynamic pressure forces and the added-mass tensor. Alternates with 13.07.
J. N. Newman

13.10J Introduction to Structural Mechanics

(Same subject as 2.071J)
Prereq.: 2.01 or 16.004
U (1)
4-0-8

Selected structural mechanics concepts applicable to marine and mechanical structures, with emphasis on beam design and analysis. Methods of computing deflection, principle of virtual forces and displacements, energy methods, and statically indeterminate structures. Theory and applications of finite-element methods in structural analysis, using computer programs. Introduces advanced topics in structural mechanics.
A. Moshaiov, J. H. Williams, Jr.

13.111 Structural Mechanics (A)

Prereq.: 13.10J
G (2)
3-0-9

Concept of deformation and equilibrium in continuum mechanics and plate and shell structures. Derivation of elastic stress-strain relations for plate and shell elements. Bending and buckling of rectangular plates. Nonlinear geometric effects. Post-buckling and ultimate strength of typical stiffened panels used in naval architecture. General theory of elastic shells and axisymmetric shells. Buckling and crushing strength of cylindrical shells.
T. Wierzbicki

13.121 Introduction to Ship Structures (A)

Prereq.: 13.10J
G (2)
2-1-6

Ship longitudinal strength and hull primary stresses. Ship structural design concepts. Role of classification societies in structural design process. Design loads. Inertia effects. Hull deflections, exact and approximate methods. Effect of superstructures and dissimilar materials on primary strength. Transverse shear stresses and thermal stresses in the hull girder. Torsional strength of ships. Effective breadth. Ship design exercises. Credit not given for both 13.121 and 13.122.
A. Moshaiov

13.122 Ship Structural Analysis and Design (A)

Prereq.: 13.10J, *13.111*
G (2)
3-2-7

Ship longitudinal strength and hull primary stresses. Ship structural design concepts. Role of classification societies in structural design process. Design loads. Inertia effects. Hull deflections, exact and approximate methods. Effect of superstructures and dissimilar materials on primary strength. Transverse shear stresses and thermal stresses in the hull girder. Torsional strength of ships. Effective breadth. Theory and applications of finite-element methods. Computer projects using beam, plane, and plate elements for ship grillages and plates. Credit not given for both 13.121 and 13.122.
A. Moshaiov

13.123 Advanced Analysis and Design of Ocean Engineering Structures (A) (Revised Content and Unit)

Prereq.: 13.111
G (1)
3-3-6

Ocean engineering structural configurations: fixed-base platforms, semi-submersibles, cable and moorings, pipelines, marine risers. Marine pressure vessels: thick cylindrical and spherical shell, instability of a thin cylindrical and spherical shell, penetrations, reinforcements, closures, hatch design, stiffened cylindrical shells. Tubular joint design. Student selects a design project using modern computer programs for strength and stability analysis.
D. G. Karr

13.124 Response of Marine Structures to Impulsive Loading (A)

Prereq.: 13.111
G (2) **Not to be offered 1989-90**
3-0-9

Characterizes extreme loads at sea. Collisions, hydrodynamic wave loading, slamming, ice impact, internal and underwater explosions. Methods of plastic analysis for large deflections of structures. Mechanics of projectile impact. Dynamic plastic behavior and crushing of stiffened plates and shells. Design for energy absorption. Crashworthiness of land, air, sea vehicles. Local damage and tearing of hull girder under transient loading. Collapse of tubular members of offshore structures. Propagating buckle in pipelines.
T. Wierzbicki

13.131 Plastic Analysis of Structures (A)

Prereq.: 13.111
G (1) **Next offered 1989-90**
3-0-9

Elastic-plastic and rigid-plastic material idealization. Yield conditions. Drucker's stability postulate. Normality, convexity, and flow rule. Limit analysis theorems. Static plastic collapse of beams, frames, plates, and shells. Plastic behavior of stiffened panels and other structures encountered frequently in ocean engineering and naval architecture. Theoretical and experimental behavior of beams, plates, and shells under dynamic loads. Comparison of first yield vs plastic collapse design concepts.
T. Wierzbicki

13.132 Advanced Structural Topics (A)

Prereq.: 13.111
G (1) **Next offered 1989-90**
3-0-6

Advanced topics in structural analysis and design with various contents. Offers students the possibility to become acquainted with some of the current research within the Department. Includes potential topics such as imperfection sensitivity and post-buckling behavior of shells, plastic buckling of structures, dynamics and creep buckling of structures, composite materials, reinforced concrete structures, behavior of ships and offshore structures in ice-infested water.
T. Wierzbicki, D. G. Karr

13.14J Structural Mechanics in Nuclear Power Technology (A)

(Same subject as 1.56J, 2.084J, 3.82J, 16.261J, 22.314J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 22.314J.
O. Buyukozturk, M. S. Kazimi

13.15 Materials for Ocean Engineering

Prereq.: —
G (2) **Next offered 1989-90**
3-0-8

Properties of metals used for the construction of ships and ocean engineering structures. Microstructures, processing, heat treatment, service behavior, and failures with special emphasis on corrosion resistance of ferrous and nonferrous metals.
K. Masubuchi

13.16J Fracture of Structural Materials (A)

(Same subject as 1.591J, 3.90J)
Prereq.: 1.02 or 13.15
G (1)
3-0-6

See description under subject 3.90J.
K. Masubuchi, F. J. McGarry

13.17J Welding Engineering (A)

(Same subject as 3.36J)
Prereq.: 13.15
G (1)
3-0-6

Detailed study of processing variables involved in joining materials by welding, brazing, and adhesive bonding. Synthesis of elementary physical phenomena such as transient heat flow, phase transformations, and dimensional changes into the complex overall reactions associated with joining. Testing, inspection, and properties of finished joints. Laboratory demonstrations of arc and other welding processes.
K. Masubuchi

13.18 Case Studies in Welding Design (A)

Prereq.: —
G (2) **Next offered 1989-90**
2-0-4

Problems occur in various welded structures, including ships, offshore oil drilling rigs, pressure vessels, bridges, and aerospace structures. Discusses problems such as brittle fracture, fatigue, weld cracking, and distortion. Through examination of past and current cases, develops techniques for preventing these problems by proper selection of materials, joining processes, and procedures during the design stages.
K. Masubuchi

13.21 Ship Power and Propulsion (A)

Prereq.: 2.40
G (1)
3-1-8

Examines ship power and propulsion systems for commercial and naval ships. Considers steam, diesel, and gas-turbine power plants, together with speed reducers and propulsors. Project study and economic evaluation of the propulsion system for a commercial or a naval ship.
A. D. Carmichael

13.25J Thermodynamics of Power Systems

(Same subject as 2.41J)
Prereq.: 2.40
U (2)
3-0-9

See description under subject 2.41J.
A. D. Carmichael, J. B. Heywood, J. L. Smith, Jr.

13.26J Thermal Power Systems (A)

(Same subject as 2.601J)
Prereq.: 2.40, 2.20, 2.51
G (2)
3-0-9

See description under subject 2.601J.
A. D. Carmichael, W. M. Rohsenow

13.39 Analysis of Techniques for Fabricating Structures (A)

Prereq.: 3.13 or 13.15 or 13.17J
G (2) **Next offered 1989-90**
2-0-4

Analyzes problems related to fabrication of structures, such as ships, aircraft, rockets, pressure vessels, buildings, and ocean engineering structures by various joining processes including welding, riveting, and adhesive bonding. Discusses problem areas such as fracture characteristics of welded structures; residual stress, distortion, and stress relieving; advanced welding metallurgy; nondestructive testing of structural welds. Laboratory demonstrations of some tests.
K. Masubuchi

13.40 Introduction to Computer-Aided Ocean Engineering Design

Prereq.: 2.01, 13.00; 2.20 or 1.60
U (2)
3-3-6

Principles of an integrated design of ocean-based structures and vehicles. Computer-aided lines generation, hydrostatics, and stability calculations for ocean engineering structures and vehicles. Resistance predictions and selection of propeller characteristics to match vehicle and power plant. Preliminary strength calculations and internal arrangements.
C. Chryssostomidis

13.411 Methods of Naval Ship-System Design (A)

(13.431)
Prereq.: 13.012 or 13.40
G (S)
3-0-9

Overview of naval ship design and acquisition process; mechanics of designing a ship system, formulation of a systematic design plan, requirements and constraints, design philosophy and design elements; selection/optimization criteria; design trade-offs; analysis of ship design trends; marginal cost factors. Design exercises and projects in application of principles.
B. Tibbitts

13.412 Principles of Naval Ship Design (A)

(13.411)
Prereq.: 13.012 or 13.40; 13.10J or 13.121 or 13.122; 13.21; 13.021
G (1)
3-3-6

Design of surface ship platforms for naval applications; formal design optimization procedures; mathematical model of ship design process; engineering and economic principles governing selection of dimensions and coefficients; influence of hull form and dimensions on mobility in calm water and rough seas; internal subdivisions for efficient arrangement and maximum survivability; damage stability. Design exercises in applications of principles.
B. Tibbitts, P. E. Sullivan

13.413 Projects in Naval Ships Conversion Design (A)

(13.451)
Prereq.: 13.411, 13.412, 13.21
G (2)
Arr.

Project studies focus on conversion design of a naval ship. A new mission requirement is defined, requiring significant ship modification. Design plan formulation. Technical aspects addressed in sufficient detail to demonstrate feasibility and desirability. Requires formal written and verbal reports. Encourages participation by several students in a single project.
B. Tibbitts, P. E. Sullivan

13.42 Design Principles for Ocean Vehicles (A) (Revised Content and Unit)

(13.41)
Prereq.: 13.40 or 13.012; *13.021*
G (2)
3-0-9

Linear systems and random processes; ocean spectra and their selection; short-term and long-term statistics. Inertia vs drag dominated flows; seakeeping and sensitivity of seakeeping performance. Maneuvering of surface and underwater vehicles; equations of motion; motion stability; control surfaces. Design exercises in application of principles.
M. S. Triantafyllou, C. Chryssostomidis

13.43 Design of Ocean Engineering Systems (A) (Revised Content and Unit)

(13.441)
Prereq.: 13.012 or 13.40; 13.10J
G (1) **Next offered 1989-90**
3-0-9

Advanced topics in designing ocean engineering systems. Wave, current, and wind forces; statistics of drift forces. Separation, oscillatory flow around bluff bodies. Vortex-induced vibrations. Galloping and flutter. Cable statics and dynamics; dynamics and design of multileg mooring systems. Riser statics and dynamics; flexible risers; towed arrays. Dynamic positioning of vehicles; modeling issues and control system design. Applications to floating structures include moored semi-submersibles and ships, and tension-leg platforms.
M. S. Triantafyllou

13.461 Projects in New Construction Naval Ship Design (A)

Prereq.: 13.411, 13.412, 13.122, 13.21
G (1, 2, S)
Arr.

Project studies focus on preliminary design of a new naval ship, fulfilling a given set of mission requirements. Design plan formulation. System level trade-off studies. Emphasizes achieving a balanced design and total system integration. Requires formal written and oral reports. Encourages participation by several students in a single project extending over two terms.
B. Tibbitts, P. E. Sullivan

13.462 Projects in Ocean Engineering System Design (A) (Revised Content)

Prereq.: 13.412 or 13.42 or 13.43 or 13.482J
G (1, 2, S)
Arr.

Determines design criteria for ocean-based systems such as ships, submersibles, platforms, and their control systems derived from a set of system mission requirements specified by the student in consultation with the instructor. Preparation of preliminary design of system fulfilling selected criteria. Students intending to take 13.462 should plan a two-term sequence, preferably beginning in the first term. Participation by several students in a single project encouraged. Primarily for graduate students in Ocean Engineering; others admitted by permission of instructor.
C. Chryssostomidis, M. S. Triantafyllou

13.471J Design and Implementation of Computer-Aided Engineering Systems (A) (New)

(Same subject as 2.157J)
Prereq.: Permission of Instructor
G (1)
3-2-7

Overview of existing CAE systems; architecture of high-performance graphic displays in engineering workstations; orthographic and perspective display transformations; parametric representation of curves and surfaces; elementary differential geometry; interactive graphics; bicubic surface patches; image generation; NC tool paths; solid modeling; advanced research topics; project management for software development. Group projects emphasize CAE system development. Programming proficiency required.
N. M. Patrikalakis, D. C. Gossard

13.472J Computational Geometry (A) (New)

(Same subject as 2.158J)
Prereq.: 13.471J
G (2)
3-0-9

Continuation of 13.471J with lectures, homeworks, and individual projects focusing on advanced research topics. Algebraic and rational polynomial parametric representation methods. Intersections and algebraic geometry. Sweeps. Blending and parallel surfaces. Trimmed patches. Solid modeling; CSG, boundary representation, octrees. Variational geometry and tolerances. Feature element discretizations. Interrogation of geometric models for design, analysis, and fabrication.
N. M. Patrikalakis, D. C. Gossard

13.481J Multivariable Control Systems I (A)

(13.47J)
(Same subject as 2.154J, 6.233J, 10.28J, 16.341J)
Prereq.: 2.14 or 6.302 or 10.35 or 16.30
G (1)
4-0-8

See description under subject 6.233J.
M. S. Triantafyllou, M. Athans, J. K. Hedrick, G. Stephanopoulos, L. Valavani

13.482J Multivariable Control Systems II (A)

(13.48J)
(Same subject as 2.155J, 6.234J, 10.29J, 16.342J)
Prereq.: 6.233J
G (2)
4-0-8

See description under subject 6.234J.
M. S. Triantafyllou, M. Athans, J. K. Hedrick, G. Stephanopoulos, L. Valavani

13.49 Maneuvering and Control of Surface and Underwater Vehicles (A) (Revised Content and Unit)

Prereq.: 13.42
G (1)
3-0-9

Maneuvering motions of surface and underwater vehicles. Derivation of equations of motion, hydrodynamic coefficients. Memory effects. Linear and nonlinear forms of the equations of motion. Control surfaces; modeling and design of control surfaces. Environmental forces, simulation of a maneuvering vehicle. Towed vehicles and their motion. Stability of motion. Principles of multivariable automatic control; effect of delays. Applications include autopilots for surface vehicles; towing in open seas; remotely operated vehicles; and single point moorings.
M. S. Triantafyllou

13.50 Numerical Methods with Applications to Marine Problems

Prereq.: 18.03, 2.10
G (1)
3-0-9

Introduces numerical methods useful in the solution of engineering problems. Representation of numbers on the computer. Round-off error. Solution of linear systems. Nonlinear equations. Eigenvalues of dynamical systems. Singular-value decomposition. Optimization methods. Fast Fourier Transforms. Differential equations. Solution of model problems from ocean engineering by finite-difference, finite-element, and spectral methods. Assigned computer problems requiring familiarity with FORTRAN 77.
P. D. Sclavounos

13.51 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

13.52 Management in Engineering

Prereq.: —
U (1)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
H. S. Marcus, D. P. Hoult

13.61 Project Management (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Review of project and development economics. Project identification and demand forecast techniques. Study of project design and planning methods such as network planning techniques, technological forecasting and evaluation methods, capital budgeting and project control, and scheduling techniques. Technical, operational, economic, and financial project analyses reviewed. Methods for selection from among project alternatives discussed. Study of procurement or contracting process. Approaches to project supervision, test, and acceptance.
E. G. Frankel

13.62 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. de Neufville, J. P. Clark

13.621 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

13.63J Advanced Reliability Analysis and Risk Assessment (A)

(Same subject as 22.40J)
Prereq.: 22.38, 22.82
G (2) **Not to be offered 1989-90**
3-0-9

See description under subject 22.40J.
N. Siu

13.631 Port Planning and Development (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Port planning and development, including offshore and prefabricated ports. Systems engineering study of one or more major port projects. Approach to planning and development of ports based on modern concepts of systems analysis. Port demand forecasting, design of port surveys, geotechnical analysis, port structural design, port and breakwater layout, port environmental impact analysis, port project design and management, port simulation, port financial and economic analysis.
E. G. Frankel

13.64 Projects in Ocean Systems Management (A)

Prereq.: Permission of Instructor
G (2)
3-3-6

Group projects based on current or past research in ocean systems management. Designed to develop student's ability to analyze problems involving ocean engineering and economics, operations research, management, and policy and the law, and integrate this information to formulate solutions. Projects may include ocean-dumping systems, deep-sea mining systems, and oil spill cleanup systems. Restricted to Course XIII-B students; others admitted by permission of instructor.
J. T. Kildow, H. S. Marcus, J. D. Nyhart, H. N. Psaraftis

13.65 Management of Manufacturing (A)

Prereq.: 13.43
G (1)
3-0-6

Analysis of manufacturing processes: facility layout, production and material flow; process and facility design; production process control; mathematical and economic analysis of production; production and inventory scheduling; management information system; organization of manufacturing plants, planning of manufacturing, measurement of capacity and productivity, management of manufacturing.
E. G. Frankel

13.651 Management of Technological Change in Manufacturing (A)

Prereq.: 6.041 or 18.444 or equivalent; 14.01 or 15.001 or equivalent
G (2)
3-0-6

Technological change from invention, acquisition, innovation, implementation, and introduction. Technology transfer and pricing. Production theory and productivity measurement. Technology forecasting and evaluation. Process and product technology change. Strategic planning, timing, choice, and scale of technological change. Hierarchical decision models. Cross-impact analysis. Managing technological change in manufacturing. Case studies from manufacturing industries.
E. G. Frankel

13.661 Economics of Ocean Transportation (A) (Revised Unit)

Prereq.: 14.120 or 15.012
G (1)
2-0-4

Studies the economics of the principal ocean transportation markets and of resource allocation to ocean transportation. Structure of the markets and of the industries involved; barriers to entry and competition; theory of international trade; spot and term freight rate formation in the tanker, dry bulk, and tramp shipping markets; analysis of risks facing the industry, charter market operators, and charterers; world petroleum transportation network; liner shipping rate making; impact of maritime policies and regulations on the industry. Meets during second half of term.
H. N. Psaraftis

13.665J Logistical and Transportation Planning Methods (A)

(Same subject as 1.203J, 6.281J, 11.526J, 15.078J, 16.76J)
Prereq.: 6.431, 15.075
G (1)
3-0-9

See description under subject 1.203J.
H. N. Psaraftis, A. I. Barnett, R. C. Larson, A. R. Odoni

13.671 Optimal Design of Engineering Systems (Revised Content)

Prereq.: 1.00 or equivalent
U (1)
3-1-8

New School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. C. Larson, H. N. Psaraftis, Y. Sheffi

13.672 Probabilistic Models in Engineering (Revised Content)

Prereq.: 1.03 or 6.041 or 18.05
U (2)
3-2-7

New School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. R. Odoni, R. C. Larson, H. N. Psaraftis

13.68 Management of Marine Systems (A) (Revised Unit)

Prereq.: Permission of Instructor
G (1)
2-0-4

Analyzes current technological, market, and regulatory trends in various segments of the marine industry and government development programs such as liner trades, vessel chartering, shipbuilding, defense systems, coastal facilities, and fishing; description of resources and constraints involved; impact of trends on management decisions; analysis of problems actually existing in the field. Meets during first half of term.
H. S. Marcus

13.685J Manufacturing/Technology Interface (A)

(Same subject as 3.565J, 15.365J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 15.365J.
J. M. Utterback

13.69 International Shipping (A)

Prereq.: 13.68
G (2)
3-0-6

Explores internal operating, financial, and marketing issues as well as external market and technological factors that define the international shipping environment. Includes effect of world energy prices and changing trade patterns upon demand for shipping; evaluation of shipping capacity requirements in terms of capital needs; new ship and terminal technologies; and effect of changing international relationships. Other students admitted by permission of the instructor.
H. S. Marcus

13.700-13.709 Special Problems in Ocean Engineering

Prereq.: —
U (1, 2, S)
Arr.

Special reading, study, design, and/or investigation under supervision of a qualified member of the staff. Topics in ocean engineering, naval architecture, or marine engineering individually arranged to suit interests of the student. Consult Department Student Administration Office for subject number that will be assigned in accordance with the technical area of the topic selected.
D. K-P. Yue

13.710-13.719 Special Problems in Ocean Engineering (A)

Prereq.: —
G (1, 2, S)
Arr.

Special reading, study, design, and/or investigation under supervision of a member of the staff. Topics in ocean engineering, naval architecture, or marine engineering individually arranged to suit interests of the student. Consult Department Student Administration Office for subject number that will be assigned by the Department in accordance with the technical area of the topic selected.
A. D. Carmichael

13.730-13.739 Seminar in Ocean Engineering

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Weekly lectures on new topics in ocean engineering by members of the MIT staff. Consult Department Student Administration Office for subject number assigned in accordance with the technical area of the topic selected. Consult Department headquarters.

13.741J Geophysical and Oceanographic Signal Processing I (A)

(Same subject as 6.455J)
Prereq.: 2.02 or 6.003, 6.041, 18.075
G (1) **Not to be offered 1989-90**
3-0-9

Systems and techniques used in oceanographic data analysis. Temporal random processes, correlation, and spectral analysis by indirect, DFT, and adaptive methods. Sonar, radar, echosounders, and seismic systems. Space/time random processes, frequency-wave number characterizations, array and spatial processing; applications in arrays for ambient noise and passive sonar, surface, and internal waves. Alternate years.
A. B. Baggeroer

13.742J Geophysical and Oceanographic Signal Processing II (A)

(Same subject as 6.456J, 12.534J)
Prereq.: 6.341 or 12.761 or 13.741J or 12.713
G (2) **Not to be offered 1989-90**
3-1-8

Advanced topics in time-series analysis and signal processing as applied to geophysical and oceanographic problems such as seismic exploration, ocean wave spectra, and acoustical propagation and noise. Covers modern spectral analysis techniques, multichannel spectral analysis, deconvolution methods, spatial random process characterization and array processing techniques. Includes development of estimation techniques commonly used in inverse problems. Lab utilizes computer implementations of topics covered.
A. B. Baggeroer

13.76 Introduction to Random Processes in Ocean Engineering (A) (Revised Content)

Prereq.: 18.075 or 18.085 or 18.302
G (2) **Not to be offered 1989-90**
3-0-9

Responses of ships and offshore structures to random forces and motions of the sea. Fundamental material covered includes elements of probability theory and statistics; harmonic analysis of both deterministic and random processes; linear systems including those with frequency-dependent parameters such as ships in a seaway; and statistics of extreme forces and motions. Applications include ocean waves, computer-aided seakeeping analysis, offshore structures in storms, and establishment of design criteria on a statistical basis.
J. H. Milgram

13.771 Engineering Internship

Prereq.: —
U (1, 2, S) [P/F]
0-6-0

13.772 Industrial Practice in Ocean Engineering

Prereq.: 13.771
U (1, 2, S) [P/F]
Arr.

13.774 Advanced Engineering Internship

Prereq.: 13.771
G (1, 2, S)
0-6-0

Enrollment restricted to students registered in Course XIII-C Program. Provides academic credit for assignments affiliated with XIII-C Program. Students register for 13.771 during their first and second company assignments, accumulating a total of 12 units. 13.772 provides academic credit for the seven-month company assignment. 13.771 and 13.772 terminate with the S.B. degree. Students register for 13.774 during their third and fourth company assignments (after admission to graduate school), accumulating a total of 12 graduate units. Credit for above given upon satisfactory completion of company assignments, receipt of favorable evaluation by company supervisor, and receipt of favorable evaluation of student's report about company assignment by faculty advisor.
C. Chryssostomidis

13.78 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
W. C. Flowers

13.80J Mechanical Vibration

(Same subject as 2.06J)
Prereq.: 2.03J or 13.003J
U (2)
3-0-9

Concepts of mechanical vibration, including free and forced vibration of single- and multi-degree of freedom systems. Modal analysis and matrix formulation of vibration problems. Approximate solution techniques. Vibration and modal analysis of continuous systems: beams, rods, and strings. Introduction to the response of linear systems to random excitation. Numerous examples and applications of vibration measurement and analysis, including vibration isolation and dynamic absorbers, ships, offshore structures, engines, and rotating machinery.
J. K. Vandiver, R. H. Lyon

13.81J Principles of Acoustics (A)

(Same subject as 2.060J, 16.081J)
Prereq.: 13.003J or 2.03J or 16.004, 18.075
G (1)
3-0-9

See description under subject 2.060J.
P. Leehey, R. H. Lyon

13.82J Sound and Structural Vibration (A)

(Same subject as 2.063J)
Prereq.: 2.03J or 16.004, 18.075
G (2)
3-0-9

See description under subject 2.063J.
P. Leehey, R. H. Lyon

13.851 Fundamentals and Applications of Underwater Sound (A)

Prereq.: 18.075
G (2)
3-0-9

Fundamentals of underwater sound systems as controlled by physical principles and properties of the ocean and its boundaries. Analyzes sonar systems. Absorption in sea water. Transmitting and receiving arrays. Scattering and reflection. Refraction and propagation loss. Noise and reverberation. Sonar design principles. Applications in charting, navigation, station keeping, target detection, fishing, petroleum exploration, telemetry.
I. Dyer

13.861 Ocean and Seabed Acoustics I (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Surveys properties of the ocean and seabed and of predictive models of sound propagation, in relation to sonar and seismic system design and/or to the use of sound to uncover oceanic properties. Ray and wave theories of propagation in vertically stratified media. Approximate propagation theories for a horizontally varying ocean. Reflection and transmission of sound by a stratified ocean bottom. Scattering from a random sea surface and seafloor. Introductory knowledge of Fourier analysis, probability, and wave propagation necessary.
A. B. Baggeroer,
(Woods Hole Staff): G. Frisk

13.862 Ocean and Seabed Acoustics II (A)

Prereq.: 13.861
G (2) **Next offered 1989-90**
3-0-9

Continuation of 13.861, treating ray and normal mode theory in greater depth, and introducing new topics. Emphasizes "state-of-the-art" level in ocean acoustics. Includes ray theory corrections, coupled normal-mode theory, adiabatic approximation, continuum and virtual modes, rough-surface scattering in mode theory, ray-mode picture connections, parabolic equation, Thomson-Haskell propagator matrix, seismic wave (body and surface) overview, WKBJ synthetic seismograms, and hydrophone-geophone intercomparisons. Permission of instructor required.
(Woods Hole Staff): J. Lynch

13.863 Ocean Seismo-Acoustics (A) (New)

Prereq.: 13.861 or Permission of Instructor
G (1)
3-0-9

Low-frequency propagation in ocean environments with special emphasis on the interaction of the acoustic field in the water column with seismic waves in seabed and ice cover. Stress wave propagation in isotropic elastic solids. The fluid-solid interface. Fluid-elastic waveguides. Effects of seismic waves on ocean sound propagation. Seismic interface and surface waves in a stratified seabed. Seismic waves in ice cover. Rough surface scattering of elastic waves. Seismo-acoustic ambient noise. Anisotropic and porous media.
H. Schmidt

13.871 Wave Scattering by Rough Surfaces and Randomly Inhomogenous Media (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

An advanced-level subject designed to give the student working knowledge of current techniques in scattering theory as applied to rough surfaces and randomly inhomogenous media. Major application of theory presented is to ocean acoustics, but can be used in other acoustic and electromagnetic applications. Includes basics of scattering theory, volume scattering by discrete scatters (aerosols), scattering by rough surfaces, satellite remote sensing using rough-surface scattering, and acoustic scattering from ocean internal waves.
(Woods Hole Staff): J. F. Lynch, S. Rajan

13.901 Ocean Engineering Laboratory I

Prereq.: 2.20
U (2) LAB
1-5-0

Experimental projects in the fields of ocean engineering and naval architecture and marine engineering, conducted at the MIT Ship Towing Tank and the MIT Variable Pressure Water Tunnel. Ocean engineering experiments arranged in order to solve one or more design problems selected by the instructor.
A. D. Carmichael

13.902 Ocean Engineering Laboratory II

Prereq.: 13.901, 13.003J
U (1) LAB
1-5-0

Experimental projects in the fields of ocean engineering and naval architecture and marine engineering, conducted at laboratory facilities in the Department of Ocean Engineering. Ocean engineering problems arranged in order to solve one or more design problems selected by the instructor.
A. D. Carmichael

13.91 Nuclear War: Threat and Avoidance

Prereq.: —
U (2) HASS
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

13.92 Marine Policy (A) (Revised Content and Unit)

Prereq.: Permission of Instructor
G (1)
2-0-4

Surveys major ocean uses and their associated policy issues. Demonstrates relationships among uses and the influence of the scientific, technical, economic, and political/legal aspects. Includes government/business relationships in offshore natural resources, maritime transportation, and waste management. Meets during first half of term.
J. T. Kildow

13.93 Nuclear Weapons and Arms Control: Technology and Policy Issues

Prereq.: —
G (1)
4-0-8

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
G. W. Rathjens, J. P. Ruina015

13.94 Law for Ocean Systems (A) (Revised Unit)

Prereq.: Permission of Instructor
G (1)
2-0-4

Legal framework for managing ocean resources and systems, combining public law of the sea, admiralty, and the US regulatory law. OCS, tanker, shipping, and environmental regimes. Law for new ocean technologies. Questions of jurisdiction and implementation arising from new economic zones or unilateral extensions. Principles governing applicability of civil and criminal law offshore. Focus on relationship of law and technology. Meets during second half of term.
J. D. Nyhart

13.95J Negotiation in Engineering Systems (New — Context Subject)

(Same subject as 15.600J)
Prereq.: —
U (1)
3-3-6

Teaches societal, economic, legal, and environmental issues pertinent to the successful negotiation of large engineering systems. Presents the skills, processes, and tools required for the synthesis of effective outcomes in complex negotiations. Up to three real contexts are studied in detail. Each week, one session focuses on teaching the elements of negotiation management, another on contextual analysis, and the third on a simulated negotiation among students.
J. D. Nyhart, H. N. Psaraftis

13.961J Proseminar in Technology and Policy I (A)

(Same subject as TPP 11J)
Prereq.: Permission of Instructor
G (1)
4-0-8

See description under TPP 11J.
J. T. Kildow, R. D. Tabors, R. de Neufville

13.962J Proseminar in Technology and Policy II (A)

(Same subject as TPP 12J)
Prereq.: TPP 11J
G (2)
3-0-6

See description under TPP 12J.
J. T. Kildow, R. Tabors, R. de Neufville

13.97 Introduction to Technology and Law

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. D. Nyhart

13.98J Coastal Zone Management (A)

(Same subject as 11.365J)
Prereq.: Permission of Instructor
G (2)
3-3-6

Methods and concepts for balanced management of land and water resources in coastal regions. Includes physical and ecological coastal processes, implications of the range of human activities that place demands on the limited coastal resource base, and institutional and regulatory framework for coastal management systems.
J. T. Kildow

13.990J Oceanographic Systems I

(Same subject as 1.697J)
Prereq.: —
G (S)
2-4-6

Orientation subject for students entering the MIT-Woods Hole Oceanographic Institution program in oceanographic engineering. Oceanographic experiments of research interest in Cape Cod waters carried through experiment design, instrumentation design, construction and testing, deployment, data taking and interpretation of results. Research teams made up of students in 13.990J and 13.991J together. Participation in summer seminars at WHOI. Given at Woods Hole Oceanographic Institution.
(Woods Hole Staff)

13.991J Oceanographic Systems II

(Same subject as 1.698J)
Prereq.: —
G (S)
2-4-6

Continuation of 13.990J during second summer term in the MIT-WHOI Joint Program in Oceanographic Engineering. Given at Woods Hole Oceanographic Institution.
(Woods Hole Staff)

13.994 Buoy Engineering (A)

Prereq.: 2.01 or 2.03J/13.003J or 13.80J; 18.03
G (2) **Not to be offered 1989-90**
3-0-6

Theoretical and practical aspects of buoy systems structural design. Stability of immersed and surface floating bodies. Wave theory. Heave and roll response of buoys to ocean wave excitation. Hydrodynamic forces on constrained bodies. Equilibrium trajectories of immersed cables. Two- and three-dimensional models for computer analysis. Dynamics of mooring lines. Outline of practical aspects of buoy system design. Buoyancy materials. Mooring line components. Anchoring. Buoy system installation and retrieval.
(Woods Hole Staff): H. O. Berteaux

13.998 Principles of Oceanographic Instrument Systems — Sensors and Measurements (A)

Prereq.: 2.03J/13.003J, 18.075
G (2) **Not to be offered 1989-90**
3-3-6

Introduces theoretical and practical principles in design of oceanographic sensor systems. Transducer characteristics for acoustic, current, temperature, pressure, electric, magnetic, gravity, salinity, velocity, heat flow, and optical devices. Limitations on these devices imposed by ocean environment. Signal conditioning and recording; noise, sensitivity, and sampling limitations; standards. Examples of system design from physical oceanography, geophysics, submersibles, acoustics. Laboratory project required.
(Woods Hole Staff): A. J. Williams

13.999J Special Projects in Oceanographic Engineering (A)

(Same subject as 1.699J)
Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Special problems in oceanographic engineering, carried out under supervision of members of the staff of the Woods Hole Oceanographic Institution. Given at Woods Hole Oceanographic Institution.
(Woods Hole Staff)

Course 14 Economics

General Economics and Theory

14.UR Undergraduate Research

Prereq.: 14.02
U (1, 2) [P/F]
Arr.

Participation in research with an individual faculty member or research group, independent research or study under the guidance of a faculty member. Admission by arrangement with individual faculty member.
P. R. Krugman

14.01 Principles of Microeconomics

Prereq.: —
U (1, 2)
3-0-6

Introduces microeconomic concepts and analysis. Supply and demand analysis, theories of the firm and of individual behavior, competition and monopoly, welfare economics. Applications to problems of current economic policy.
Term 1: *A. Shepard*
Term 2: *F. M. Fisher*

14.014J Engineering Aspects of Economic Analysis

(Same subject as 1.01J)
Prereq.: —
U (2)
3-2-7

See description under subject 1.01J. Credit is not given to both 14.014J and 1.01J. Consult K. D. Stolzenbach.

14.02 Principles of Macroeconomics

Prereq.: —
U (1, 2)
3-0-6

Provides an overview of macroeconomic issues: the determination of output, employment, unemployment, interest rates, and inflation. Monetary and fiscal policies are discussed, as are the public debt and international economic issues. Introduces basic models of macroeconomics and illustrates principles with the experience of the US and foreign economies.
Term 1: *P. A. Diamond*
Term 2: *P. R. Krugman*

14.03 Applied Microeconomics

Prereq.: 14.01
U (1, 2)
3-0-6

Designed for nonmajors who desire further exposure to microeconomics and its applications. Presents basic theory of consumer and producer behavior and welfare analysis at an intermediate level. Emphasizes applications, including cost-benefit analysis, transportation, price regulation, research and development, and pollution.
Term 1: *W. C. Wheaton*
Term 2: *J. E. Harris*

14.04 Intermediate Microeconomic Theory

Prereq.: 14.01
U (1)
4-0-8

Basic theory of consumer behavior, production and costs, partial equilibrium analysis of pricing in competitive and monopolistic markets, general equilibrium, welfare, and capital. Credit not given for both 14.03 and 14.04. May *not* count toward HASS Requirement.
P. M. Aghion

14.06 Intermediate Macroeconomic Theory (Revised Content)

Prereq.: 14.02
U (1, 2)
4-0-8

Extension of 14.02, with special emphasis on the role of expectations and the open economy, and an eye on current developments. The effects of US fiscal deficits on the US economy, on the rest of the world. Trade and fiscal deficits. The long-run costs of deficit finance. The stock market crash: explanations and implications. The recent UK and US disinflations.
Term 1: *D. Quah*
Term 2: *R. M. Solow*

14.09 Reading Seminar in Economics

Prereq.: 14.04, 14.06
U (1) [P/F]
Arr.

Reading and discussion of particular topics in economics. Open to undergraduate students by arrangement with individual faculty members. Consult Department headquarters.
R. S. Eckaus

14.101 Mathematics for Economists

Prereq.: 18.02
G (1)
4-0-8

Linear algebra, emphasizing topics of interest to economists. Also topics in multivariate differential calculus and optimization theory. Provides mathematical prerequisites for econometrics.
J. E. Harris

14.102 Introduction to Game Theory (A)

Prereq.: —
G (1)
2-0-4

A half-semester course, introducing Nash equilibrium, subgame perfection, the Folk Theorem, Bayesian equilibria, the Revelation Principle, sequential equilibrium, signaling games, and reputation. A prerequisite for the advanced theory sequence, 14.126 and 14.147.
M. Dewatripont

14.103 Introduction to Optimization (A)

Prereq.: —
G (1)
2-0-4

Unconstrained optimization. Constrained optimization, Lagrange and Kuhn-Tucker multipliers, linear programming. Dynamic programming and the Pontryagin method.
P. M. Aghion

14.111J Economics of Project Evaluation (A)

(Same subject as 1.148J)
Prereq.: 14.03
G (2)
3-0-6

Economic concepts of costs and benefits: consumers' and producers' surplus; shadow prices; and valuation of nonmarket costs and benefits. Investment criteria and the discount rate: static and dynamic; treatment of risk and uncertainty. Pricing policies and investment rules. Case studies in developed and underdeveloped countries.
J. Rothenberg

14.12 Economic Applications of Game Theory

Prereq.: 14.01
U (2)
3-0-6

Analysis of strategic behavior in multi-person economic settings. Introduction to Nash equilibrium and its refinements, subgame-perfect equilibrium, and sequential equilibrium. Applications drawn from labor economics, the economics of organization, industrial organization, and international trade.
M. Dewatripont

14.121 Microeconomic Theory I (A)

Prereq.: 14.04
G (1)
2-0-4

Prereq.: Theory of production, including duality, competitive markets, monopoly, and oligopoly.
P. A. Diamond

14.122 Microeconomic Theory II (A)

Prereq.: 14.04
G (1)
2-0-4

Theory of consumption and general equilibrium.
D. L. McFadden

14.123 Microeconomic Theory III (A)

Prereq.: 14.122
G (2)
2-0-4

Welfare theory, externalities, public goods, second-best analyses.
M. Weitzman

14.124 Microeconomic Theory IV (A)

Prereq.: 14.122
G (2)
2-0-4

Capital theory, one- and two-sector growth theory, resource use, introduction to uncertainty theory.
J. M. Tirole

14.125 General Equilibrium (A)

Prereq.: 14.04
G (1) **Next offered 1989-90**
2-0-4

Theory of general competitive equilibrium from modern mathematical points of view. Topics include properties of aggregate demand functions, existence of equilibrium, fixed-point theorems and computational techniques, core of an economy, nonconvexities, stability and uniqueness of equilibrium, and empirical general equilibrium models.
O. D. Hart

14.126 Game Theory (A) (Revised Unit)

Prereq.: 14.122
G (2)
3-0-9

How should economic agents act when their optimal decisions depend on what they expect other agents to do? We study various models of equilibrium, which correspond to different ways that the agents might make their decisions, and various kinds of games — static games, dynamic games, and games of incomplete information. The course focuses on concepts and techniques, but also covers applications to industrial organization, bargaining, and internal organization.
D. Fudenberg

14.127 Economics of Uncertainty (A)

Prereq.: 14.124
G (1)
3-0-9

Individual behavior under uncertainty. Equilibrium and welfare with uncertainty. Search and information.
P. M. Aghion

14.128 Mathematical Optimization and Economic Theory (A)

Prereq.: 14.124
G (1) **Next offered 1989-90**
2-0-4

Linear and nonlinear programming, duality theory, dynamic programming, and optimal control. Half-term subject.
M. L. Weitzman

14.129 Contract Theory (A)

(14.193, 14.194)
Prereq.: 14.121, 14.451
G (2)
3-0-6

Recent developments in contract theory. Introduces theory of mechanism design and considers applications to optimal contracting problems such as auction design, regulation, nonlinear pricing and labor contracts. Also covers agency theory and incomplete contracting and some applications.
M. Dewatripont

14.141 Disequilibrium Foundations of Equilibrium Economics (A)

Prereq.: 14.122
G (1) **Next offered 1989-90**
2-0-4

Does a competitive economy, with rational agents taking advantage of disequilibrium opportunities for arbitrage, tend to approach equilibrium? Is that equilibrium competitive? Importance of the subject for the foundations of usual economic analysis and the theory of value. Historical review and modern theory of stability in relation to above questions. Half-term subject.
F. M. Fisher

14.144 Applied Price Theory (A)

Prereq.: 14.122
G (2)
Arr.

Selected topics in price theory, with focus changing from year to year. Currently emphasizes the economics of exhaustible and renewable natural resources.
R. M. Solow

14.147 Topics in Game Theory (A) (Revised Unit)

Prereq.: 14.126
G (1)
3-0-9

Advanced course on topics of current research interest. Possible topics include repeated games with moral hazard, games played by automata, learning rules and bounded rationality in games, and various types of equilibrium refinements.
D. Fudenberg

14.148 Advanced Topics in Microeconomic Theory (A)

Prereq.: 14.124
G (1)
Arr.

14.149 Advanced Topics in Microeconomic Theory (A)

Prereq.: 14.124
G (2)
Arr.

Advanced topics in microeconomic theory of current interest. Consult Department headquarters.

14.15J Accounting for the Social Consequences of Technological Change (New — Context Subject)

(Same subject as 2.94J)
Prereq.: 14.01, 14.02, and 14.03; 2.70; and for engineering majors, 2.40
U (2)
2-0-7

Examines various indirect effects of technological change on work, health, lifestyle, environment, etc. Three case studies chosen by class. Teams of students identify and evaluate indirect costs and benefits. Teams propose methods to take these into account in decision making via government regulatory or tax intervention or private voluntary action. Intended for juniors and seniors with engineering and economics training. May *not* count toward HASS Requirement.
D. G. Wilson, J. Rothenberg

14.191 Economic Analysis of Law (A)

Prereq.: 14.04
G (2) **Next offered 1989-90**
3-0-6

Advanced subject on selected topics in law and economics. Property rights; contracts and impossibility; law enforcement and deterrence; negligence vs strict liability; no-fault systems; lump-sum vs periodic damages. Emphasis on empirical applications, including medical malpractice, products liability, and information disclosure.
J. E. Harris

14.193 Seminar: Topics in Economics (A)

Prereq.: 14.121, 14.451
G (1, 2)
Arr.

14.194 Seminar: Topics in Economics (A)

Prereq.: 14.121, 14.451
G (2)
Arr.

Reading and discussion of special topics in economics. Open to advanced graduate students by arrangement with individual members of the staff. Consult Department headquarters.

14.195, 14.196 Reading Seminar in Economics (A)

Prereq.: 14.121
G (1, 2) [P/F]
Arr.

Reading and discussion of special topics in economics. Open to advanced graduate students by arrangement with individual members of the staff. Consult Department headquarters.

14.198, 14.199 Teaching Introductory Economics

Prereq.: —
G (1, 2) [P/F]
2-0-2

Required of teaching assistants in introductory economics (14.01 and 14.02), under supervision of the faculty member in charge of the subject.
14.198: *F. M. Fisher*
14.199: *R. Dornbusch*

Industrial Economics

14.20 Industrial Organization and Public Policy

Prereq.: 14.01
U (1)
3-0-6

Analyzes the structure, behavior, and performance of industrial markets in the US economy. Topics include the measurement of monopoly power, behavior of firms in oligopoly markets, static and dynamic measures of market performance, antitrust policy, and public utility regulation.
A. L. Shepard

14.21J Health Economics

(Same subject as HST 901J)
Prereq.: 14.01
U (2)
3-0-6

Applies theoretical and empirical tools of economics to problems of health and medical care delivery. Concentrates on selected problems such as the welfare economics of "health" as a commodity, hospitals and the nonprofit sector, human capital and medical manpower, and innovation in medicine.
J. E. Harris

14.23 Government Regulation of Industry

Prereq.: 14.01
U (2)
3-0-6

Examines economic rationale for and against government regulation of prices, entry, product quality, and production processes in various US industries. Theoretically and empirically examines economic effects of current regulatory practices through case studies.
P. L. Joskow

14.24 Law and Economics

Prereq.: 14.01
U (2) **Next offered 1989-90**
3-0-6

Analysis of the role of the legal system in providing an appropriate framework for market transactions and in encouraging efficient resource allocation. Contracts, torts, and property law emphasized. Cases considered along with general theory. Consult Department headquarters.

14.271 Industrial Organization (A)

Prereq.: 14.04
G (1)
3-0-9

Covers theoretical and empirical work dealing with the structure, behavior, and performance of firms and markets. Topics include the organization of the firm, monopoly, price discrimination, oligopoly, monopolistic competition, product selection, advertising, and research and development. A serious effort is made to integrate theoretical and empirical work in each area.
G. Saloner, R. Schmalensee

14.272 Government Regulation of Industry (A)

Prereq.: 14.04
G (2)
3-0-9

Use and evaluation of a variety of public-policy instruments that affect the behavior and performance of industrial markets, such as antitrust policy, public utility regulation, consumer protection, environmental policy, peak-load pricing, and public enterprise.
P. L. Joskow, A. L. Shepard

14.286J Health Economics Seminar (A)

(Same subject as HST 903J)
Prereq.: 14.04
G (2)
3-0-9

Advanced subject in economics of health-care sector. Considers selected topics in depth, such as design and financing of health insurance, behavior of nonprofit hospitals, role of competition in the medical care market, determinants of technological change, and effects of government regulations. Permission of instructor required.
J. E. Harris

14.291 Industrial Economics Seminar (A)

Prereq.: 14.04
G (1) **Next offered 1989-90**
3-0-6

Particular problems in industrial organization, including economic issues in standardization, implicit collusion in the presence of fluctuating demand, and the role of incentive theory in industrial organization. Consult Department headquarters.

Statistics and Econometrics

14.30 Introduction to Statistical Method in Economics

Prereq.: 18.02
U (1, 2) SD
4-0-8

Self-contained introduction to statistics with economic applications. Elements of probability theory, sampling theory, statistical estimation, regression analysis, and hypothesis testing. Elementary econometrics and other applications of statistical tools to economic data. May *not* count toward HASS Requirement.
Term 1: *J. Wooldridge*
Term 2: *Staff*

14.31 Econometrics

Prereq.: 14.30
U (1, 2) LAB
3-4-5

Introduces basic econometric techniques, strongly emphasizing applications. Problems in estimating such economic variables as consumption-income-price relationships, production functions, and in simulating economic models. May *not* count toward HASS Requirement.
Term 1: *H. S. Farber*
Term 2: *J. Wooldridge*

14.38 Junior Paper (New)

Prereq.: One economics field subject
U (1)
0-6-0

For junior majors. Writing a research paper at least ten pages long on a topic in any economics field taken as a course or studied in a UROP assignment. Comparable in scope to a term paper, but displaying both expository and technical competence, the paper is designed to prepare juniors for thesis writing. A term or UROP paper can be used as the starting point for a Junior Paper, but credit under 14.38 will be granted only when the paper is substantially revised. The paper is to be written (revised) under the supervision of a faculty member and must be approved by June 1 of the junior year. Consult A. Shepard.

14.381 Statistical Method in Economics (A)

Prereq.: 18.02
G (1)
4-0-8

Self-contained introduction to probability and statistics as background for advanced econometrics. Elements of probability theory; sampling theory; asymptotic approximations; decision-theory approach to statistical estimation focusing on regression, hypothesis testing, and maximum-likelihood methods. Illustrations from economics and application of these concepts to economic problems.
D. L. McFadden

14.382 Econometrics I (A)

Prereq.: 14.101, 14.381
G (2)
4-0-8

Specification and estimation of the linear regression model. Departures from the standard Gauss-Markov case include heteroscedasticity, serial correlation, and errors in variables. Theory and estimation techniques for generalized least squares and instrumental variables. Economic applications are discussed.
J. A. Hausman, J. Wooldridge

14.383 Econometrics II (A)

Prereq.: 14.382 or Permission of Instructor
G (1)
4-0-8

Theory and application of more advanced econometric specifications, including multivariate regression, identification in simultaneous equations models, and systems estimation of simultaneous equations models.
J. A. Hausman, D. Quah

14.384 Time-Series Analysis (A)

Prereq.: 14.382 or 14.388
G (2)
4-0-8

Theory and applications of time-series models, including stochastic processes, ARIMA processes, spectral analysis, and distributed lags.
D. Quah, J. Wooldridge

14.385 Nonlinear Econometric Analysis (A)

Prereq.: 14.382 or Permission of Instructor
G (2)
4-0-8

Nonlinear and maximum-likelihood econometric models, including estimation and identification of nonlinear simultaneous equations models, censored and truncated specifications, and discrete dependent variables.
D. L. McFadden, T. Stoker

14.386 Advanced Topics in Time Series (A)

Prereq.: 14.383
G (2) **Next offered 1989-90**
2-0-4

Covers more technical results and tools useful in time-series analysis: asymptotic distribution theory for heterogeneous and serially correlated data, Fourier techniques, continuous-time methods, multivariate restricted dynamic models. Extensions, if there is sufficient interest, might cover bootstrap analysis in inference, fast computational techniques, and others.
D. Quah

14.388 Applied Econometrics (A)

Prereq.: 14.101, 14.381
G (2)
3-0-9

Theory and practice of econometrics. The linear regression model, tests of hypotheses, generalized least squares, distributed lags, and simultaneous equations. Emphasizes applications.
E. Berndt, D. L. McFadden

14.389 Econometrics Paper (A)

Prereq.: 14.382 or 14.31
G (1)
0-0-3

Paper in econometrics required of all Ph.D. candidates who do not take 14.383.
F. M. Fisher

14.39 Undergraduate Thesis Seminar

Prereq.: 14.04, 14.06, 14.31
U (1)
2-0-4

Develops a thesis proposal through critical reading of current research, review, and written commentary on topical literature, individual reports, and conferences. For senior economics majors. Half-term subject.
J. M. Poterba

14.391 Workshop in Economic Research (A)

Prereq.: 14.124, 14.454
G (1) [P/F]
2-0-10

14.392 Workshop in Economic Research (A)

Prereq.: 14.124, 14.454
G (2) [P/F]
2-0-10

Develops research ability of students through intensive discussion of dissertation research as it proceeds, individual or group research projects, and critical appraisal of current reported research. Workshops divided into various fields, depending on interest and size. Consult Department headquarters.

For additional related subjects in Statistics, see:

Civil Engineering: 1.03, 1.06, 1.15, 1.151, 1.152, 1.202J, 1.205 and 1.732

Electrical Engineering and Computer Science: 6.041, 6.231, 6.262, 6.264, 6.431, 6.432, and 6.435

Management: 15.034, 15.061, 15.065, 15.074, 15.075, 15.076J, 15.077, 15.306, 15.572, and 15.832

Mathematics: 18.05, 18.175, 18.177, 18.313, 18.440, 18.441, 18.443, 18.445J, 18.446, 18.448, 18.454, 18.455, 18.456, 18.458, 18.465, and 18.466

See also: 2.061, 2.845, 5.72, 7.011, 8.044, 8.08, 10.816, 11.220, 11.222, 16.321, 16.37, 16.371, 17.842, 17.846, 17.850, 22.38, 22.40J, and HST 191

National Income and Finance

14.40 Monetary and Banking Policy

Prereq.: 14.06
U (2)
3-0-9

Monetary factors affecting the level of national income and relationships of financial institutions to these factors. Financial organization of society: the money-banking system, credit institutions, capital markets, and international financial relations. Monetary history.
D. Quah

14.42 Economics of Pollution

Prereq.: 14.01
U (1) **Next offered 1989-90**
3-0-6

Market processes with negative-good byproducts of production and consumption. Externalities in negative-good processes. Models of pollution and congestion. Nature of suboptimalities and the public-policy problems. Approaches to public policy: property rights, controls, subsidies, public investment, pollution and congestion charges.
J. Rothenberg

14.43 Public Finance

Prereq.: 14.03 or 14.04; 14.06
U (2) **Next offered 1989-90**
3-0-9

Analyzes effect of taxation on microeconomic activity. Examines directions for tax reform. Income and corporation tax, Social Security programs.
J. Rothenberg

14.451 Macroeconomic Theory I (A)

Prereq.: 14.06
G (2)
2-0-4

Macroeconomic analysis of general equilibrium. Financial markets and the money supply process. Models of asset demand and the channels of transmission of monetary and fiscal policy. Half-term subject.
R. Dornbusch

14.452 Macroeconomic Theory II (A)

Prereq.: 14.451
G (2)
2-0-4

Determination of aggregate output, employment, and prices. Keynes and alternative theories. The Phillips Curve. Inflation in the short and long run. Half-term subject.
R. Dornbusch

14.453 Macroeconomic Theory III (A)

Prereq.: 14.452
G (1)
2-0-4

Consumption and portfolio decisions under uncertainty. Investment and finance decisions under uncertainty. Theory and empirical evidence. Half-term subject.
O. Blanchard

14.454 Macroeconomic Theory IV (A)

Prereq.: 14.453
G (1)
2-0-4

Quantitative macroeconomics. Consumption, investment, and other components of aggregate demand. Structure of complete econometric models of the US economy. Half-term subject.
R. M. Solow

14.458 Advanced Topics in Macroeconomic Theory (A)

Prereq.: 14.454
G (2) **Next offered 1989-90**
2-0-4

Deals with certain technical aspects of applied macroeconometric research. Background in time-series econometrics and the theory of stochastic processes is assumed and applied to concrete research problems. If there is sufficient interest, will also cover the relation between dynamic macroeconometrics, Arrow-Debreu constructs, and equilibrium theory. Associated mathematical tools (basic functional analysis, contraction mapping results) developed if necessary.
D. Quah

14.459 Advanced Topics in Macroeconomic Theory (A)

Prereq.: 14.454
G (2) **Next offered 1989-90**
2-0-4

Advanced topics in macroeconomic theory of current interest.
R. M. Solow

14.462 Monetary Economics I (A)

Prereq.: 14.122, 14.452
G (1)
3-0-9

Dynamics of capital accumulation. Role of money and effects of inflation. Existence and real effects of bubbles. Dynamic behavior under uncertainty. Dynamic efficiency under uncertainty. Real business cycles. Sources of fluctuations. Asset pricing.
M. Woodford

14.463 Monetary Economics II (A)

Prereq.: 14.122, 14.452
G (2)
3-0-9

Dynamic behavior of wages and employment in labor markets, role of contracts, unions, efficiency wages. Pricing and output in the goods market; pricing under imperfect competition. Money, interest rates and credit rationing. Real rigidities, menu costs and fluctuations. Role of policy.
O. J. Blanchard, P. A. Diamond

14.471 Fiscal Economics I (A)

Prereq.: 14.04
G (1)
3-0-9

First- and second-best fiscal theory (income distribution, public goods, externalities; deadweight burden, Ramsey Problem). Incidence models. Economic response to taxation.
J. M. Poterba

14.472 Fiscal Economics II (A)

Prereq.: 14.04
G (2)
3-0-9

Quantitative analysis of economic effects of fiscal instruments and fiscal changes such as negative income tax, corporate income tax integration, general fiscal incidence, expenditure taxation.
J. A. Hausman, J. M. Poterba

14.474 Advanced Topics in Public Economics (A)

Prereq.: 14.124
G (2) **Next offered 1989-90**
2-0-4

This course considers issues of current research interest in public economics. This year, the course centers on public policy and the corporate sector. Topics include corporate investment and financing decisions, regulation of security markets, and the government's influence on risk-sharing arrangements.
J. M. Poterba

14.476 Social Insurance (A)

Prereq.: 14.121, 14.122
G (2) **Next offered 1989-90**
3-0-9

Theory of social insurance and examination of some existing and proposed US programs, including some subset of Social Security, Unemployment Compensation, Worker's Compensation, National Health Insurance.
P. A. Diamond

14.482 Income Distribution Economics (A)

Prereq.: 14.124
G (2) **Next offered 1989-90**
3-0-9

Modern theories and empirical studies of the determinants of the distribution of income.
L. C. Thurow

14.490J Advanced Financial Economics: I (A) (Revised Unit)

(Same subject as 15.440J)
Prereq.: 15.416
G (1)
3-0-9

See description under subject 15.440J.
C-F. Huang

14.491J Advanced Financial Economics: II (A) (New)

(Same subject as 15.441J)
Prereq.: 15.416
G (2)
3-0-9

See description under subject 15.441J.
J. E. Parsons

International, Interregional, and Urban Economics

14.51J Economic Structure of Cities

(Same subject as 11.008J)
Prereq.: 14.01
U (1)
3-0-6

Analyzes urban problems in the US using an economic methodology. Metropolitan growth and suburbanization, housing markets, segregation and urban renewal, transportation systems, ghetto economic development, municipal finance, and social service provision. Develops theoretical perspectives primarily through discussion of policy issues.
W. C. Wheaton

14.53 Comparative Economic Systems (Revised Unit)

Prereq.: 14.01
U (1)
3-0-9

Comparative study of the treatment of economic problems under different economic systems, including utopianism, Marxism, various forms of capitalism, and various forms of socialism. Analytic treatment of some topics in growth and planning. Comparison of several capitalist and socialist economies, including the US and USSR.
M. L. Weitzman

14.54 International Trade

Prereq.: 14.03 or 14.04
U (1)
3-0-9

Theory of international trade and finance, and application to current problems such as exchange restrictions, economic development, and foreign aid.
P. R. Krugman

14.573J Spatial Economics, Urban Markets, and Public Policy (A)

(Same subject as 1.283J, 11.410J)
Prereq.: 14.03
G (1)
3-0-9

Economic analysis of location, housing markets, urban land use, regional development, and systems of cities. Particular emphasis on the ability of spatial and urban markets to allocate resources efficiently, and the role of public-sector intervention.
J. Rothenberg, W. C. Wheaton

14.574J Fiscal Federalism and the Local Public Sector (A)

(Same subject as 11.411J)
Prereq.: Permission of Instructor
G (2)
3-0-9

The role of public goods, services, and infrastructure in the operation of metropolitan areas. The efficient provision and pricing of such services. State and local taxation and their effects on resource allocation. Fiscal competition among jurisdictions, and the movement of households and firms in response. The optimal assignment of responsibility to levels of government.
W. C. Wheaton

14.581 International Economics I (A)

Prereq.: 14.04
G (1)
3-0-9

Theory of international trade and applications in commercial policy.
P. R. Krugman

14.582 International Economics II (A)

Prereq.: 14.06, 14.581
G (2)
3-0-9

Adjustment in international economic relations, with attention to foreign exchange markets, balances of payments, and the international monetary system.
R. Dornbusch

Labor Economics and Industrial Relations

14.63 Labor in Industrial Society (Revised Content)

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Offers students a cultural and historical overview of the organization of labor in industrial society from colonial times to the present. Course material has been selected to obtain a broad overview of issues at the workplace such as changes in the labor force, collective bargaining, alternative systems of labor-management relations, comparable worth, and technology and human resource policy. Course readings include political and economic theories, historical surveys, and case studies of workers and plants.
M. Piore

14.64 Labor Economics and Public Policy

Prereq.: 14.01
U (1)
3-0-6

Theory and evidence concerning the functioning of the labor market. Particular emphasis on the roles played by government and unions. Topics include minimum wages, labor market effects of social insurance and welfare programs, the collective bargaining relationship, discrimination, and unemployment. Permission of instructor required for students without 14.01 background.
L. Lynch

14.671J Labor Economics I (A)

(Same subject as 15.671J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

An introduction to labor economics, stressing various approaches to labor market analysis. Special attention devoted to theories of worker motivation and behavior, the structure of labor markets, the determinants of wage levels and unemployment, and the historical evolution of labor market institutions.
M. Piore

14.672J Labor Economics II (A)

(Same subject as 15.672J)
Prereq.: 14.04
G (2)
3-0-6

Neoclassical analysis of the labor market and its institutions. A systematic development of the theory of labor supply, labor demand, and human capital theory. Topics discussed also include theories of wage and employment determination over the life cycle, turnover, search and unemployment, and equalizing differences. In addition, the analysis of union behavior and the role of unions in the labor market are covered. Particular emphasis on empirical evidence throughout.
H. S. Farber

14.673J Labor, Public Policy, and Income Distribution (A) (Revised Unit)

(Same subject as 15.673J)
Prereq.: 14.64 or 15.663
G (1)
3-0-9

A course on the economic analysis of labor problems and income distribution that are the focus of public policy, with emphasis on the development of appropriate conceptual frameworks and the evaluation of relevant empirical evidence. Some of the topics discussed include discrimination, welfare programs, income policies, health and safety regulation, minimum wages, theories of unemployment, employment and training programs. The topics discussed in a given semester vary.
H. S. Farber, R. Blank

14.674J Comparative Systems of Industrial Relations and Human Resource Development (A)

(Same subject as 15.674J, STS 505J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

See description under subject 15.674J.
M. Piore, R. J. Thomas

14.675J Earnings (A) (Revised Content and Unit)

(Same subject as 15.675J)
Prereq.: 14.672J or Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Provides an introduction to modern theories of earnings that emphasize learning and incentives. The goals of the course are: (1) to demonstrate the usefulness of these theories for understanding the operation of labor markets and interpreting existing empirical work, and (2) to suggest how these theories might help guide future empirical investigations. Information: H. S. Farber

14.676 Organizations (A) (New)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

A seminar exploring the economics of organizations and institutions, with special reference to the possibilities and problems of drawing on insights from organization theory, anthropology, and sociology.
R. Gibbons, M. Piore

14.691J Research Seminar in Industrial Relations (A)

(Same subject as 15.691J)
Prereq.: —
G (1)
3-0-6

14.692J Research Seminar in Industrial Relations (A)

(Same subject as 15.692J)
Prereq.: —
G (2)
3-0-6

See description under subject 15.691J, 15.692J.
Information: R. B. McKersie.

Economic History

14.71 Economic History

Prereq.: 14.01, 14.02
U (1) HUM-D
3-0-9

The spread of industrialization from Britain to the rest of Europe and beyond in the 19th century. The collapse of the 19th-century economic system in the Great Depression. The legacy of the Depression and World War II for the world economy.
P. Temin

14.731 Economic History (A)

Prereq.: 14.04, 14.06
G (1)
3-0-9

A survey of world economic history, designed to introduce economics graduate students to the subject matter and methodology of economic history. Topics chosen to show a wide variety of historical experience and illuminate the process of industrialization.
P. Temin

14.732 American Economic History (A)

Prereq.: 14.04, 14.06
G (2)
3-0-9

The rise of the US from an agricultural colony to a manufacturing power. Consideration of both microeconomic (railroads, slavery, tariffs) and macroeconomic (wars, the Depression) topics. Comparison with other economies.
P. Temin

Economic Development

14.74 Economic Growth and Development

Prereq.: 14.02
U (2)
3-0-6

Analytical treatment of the problems of economic growth and development, combined with comparative studies of the growth of advanced and underdeveloped economies. Considers policy measures to promote economic development and growth.
R. S. Eckaus

14.771 Development Economics: Microeconomic Issues and Policy Models (A)

Prereq.: 14.121, 14.122
G (1)
3-0-9

National income estimation and welfare evaluation, social accounting matrices. Agricultural issues: peasant behavior, land tenancy, factor markets, and factor payments. Urban employment, rural-urban migration, and urban bias. Rationale and experience of development planning, aggregate growth models, multisector static and dynamic programming models, general equilibrium models, cost-benefit analysis.
R. S. Eckaus

14.772 Development Economics: Macroeconomics and International Complications (A)

Prereq.: 14.121, 14.451
G (2)
3-0-9

Quantitative study of development patterns. Macroeconomics of poor countries: stabilization policy (orthodox and structuralist approaches); financial reform; terms-of-trade; cumulative processes affecting income distribution, output, and population growth. Trade patterns, international debt, and transnationals. Orthodox, structuralist, and Marxist theories of trade and development.
L. J. Taylor

14.778J Theories of Economic Development

(Same subject as 11.486J)
Prereq.: *11.210*
G (1)
3-0-6

See description under subject 11.486J.
L. J. Taylor

14.780 Alternative Approaches to Macroeconomic Theory: Distribution, Growth, and Price Formation (A)

Prereq.: 14.04, 14.06
G (2)
3-0-9

Reviews neoclassical and nonneoclassical (Marxian, Cambridge-style, and other) rules describing growth and distribution models. Recent topics in Marxian debate: joint production and measurement of surplus, unequal exchange, falling rate of profit. Cambridge models: price formation, reswitching, growth. Structuralist models: underdevelopment, monetary issues.
L. J. Taylor

14.781J Political Economy I: Theories of the State and the Economy (A)

(Same subject as 17.156J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

See description under subject 17.156J.
S. Berger, M. Piore

14.782 Comparative Economic Systems (A)

Prereq.: 14.122
G (2)
3-0-9

A comparative study of various forms of economic systems, their theoretical properties and their histories. Topics may include common property economies, various forms of capitalism, utopianism, classical Marxism, market socialism, centrally planned economies, and workers' management. Some emphasis on the economic development of the Soviet Union as an important example, with discussion of planning issues, Soviet industrial and agricultural strategies, and growth models. A few other economies may also be treated topically — e.g., Yugoslavia, China and Japan.
M. L. Weitzman

Course 15 Management

Managerial Economics

15.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Extended participation in the work of a research group which includes such activities as independent study of the literature, direct involvement in the group's research (commensurate with the student's skills and preparation), or project work under an individual faculty member extending over more than one term. Admission by arrangement with individual faculty member.
J. D. Sterman

15.002 Introduction to Applied Microeconomics

Prereq.: —
G (1) [P/F]
2-0-4

Introduces basic principles of microeconomics and applies them to management decision making and analysis of public policy. Restricted to graduate students in Sloan School of Management. Consult R. L. Schmalensee or E. R. Berndt.

15.003 Introduction to Applied Macroeconomics

Prereq.: —
G (1) [P/F]
2-0-4

Introduces basic principles of macroeconomics and applies them to management decision making and analysis of public policy. Restricted to graduate students in Sloan School of Management. Consult K. A. Froot.

15.011 Applied Microeconomics

Prereq.: 14.01
G (1)
3-0-6

Applies basic principles of microeconomic analysis to management decision making and analysis of public policy. Cost and production, utility and demand, competitive and noncompetitive market behavior. Analyzes pricing and related policies. Rationales for and effects of antitrust and government regulation.
E. R. Berndt, R. S. Pindyck, R. L. Schmalensee

15.012 Applied Macro- and International Economics

Prereq.: 14.02
G (2)
3-0-6

Macroeconomics, international trade, and finance, emphasizing implications for business behavior. Macroeconomic topics: business cycles and their effects on industries, monetary and fiscal policy, inflation and unemployment, long-term economic growth, macroeconomic forecasting. International topics: balance of payments, exchange rates, trade and specialization, trade policy and international competition, international lending and investment, the international debt problem and world financial system.
J. J. Rotemberg, K. A. Froot

15.013 Industrial Economics for Strategic Decisions (A)

Prereq.: 15.011 or 15.001
G (1, 2)
3-0-6

Applies principles of industrial economics most relevant for corporate strategy to analysis of particular industries. Topics: market structure and its determinants; rational strategic behavior in "small numbers" situations; strategies for price and nonprice competition; dynamic pricing, output, and advertising decisions; entry and entry deterrence; evolution of industries.
R. S. Pindyck, R. L. Schmalensee, T. M. Stoker

15.014 Macroeconomic Problems and Policies (A)

Prereq.: 15.012
G (1)
3-0-6

Focuses on determination of aggregate economic variables of interest to business and the use and interpretation of macroeconomic models and forecasts. Discusses the design of macroeconomic stabilization policies and the role of macroeconomic institutions like the Federal Reserve.
J. J. Rotemberg

15.016 Public-Sector Economics and Finance (A)

Prereq.: 15.012
G (2) **Next offered 1989-90**
3-0-6

Analyzes investment and operating choices where strong interdependence of public policy and private action exists. Evaluates government intervention through expenditures, financial subsidy, taxation, regulation and public participation, and private response in environments that these actions create. Sample applications in energy and natural resources, environmental control, industrial promotion. Content relevant to private firms, public agencies, and their consultants. Consult H. D. Jacoby.

15.017 Strategic Uses and Effects of Government Regulation (A)

Prereq.: 15.011 or 15.001 or 14.01
G (2)
3-0-6

Government regulation of business activity, the strategic uses of regulation by firms, and business and market responses to government policies. Discusses principles and problems of merger and anti-trust policy, financial and securities regulations, safety and environmental policies, utility regulation and transportation policy. Selected industry studies may include airlines, telecommunications, nuclear power, banking, and biotechnology.
N. L. Rose, R. L. Schmalensee

15.018 Economics of International Business (A)

Prereq.: 15.012
G (1, 2)
3-0-6

Studies key factors shaping the international economic environment and their implications for business. Topics: the causes of exchange-rate volatility, its effects, and its implications for business strategy; international lending and country risk, emphasizing causes and prediction of debt crises; international competition, including both competitive strategies of firms and effects of international trade and industrial policies.
J. J. Rotemberg, K. A. Froot

15.019 Energy Economics and Policy (A)

Prereq.: 15.011 or 15.001 or 14.01
G (1) **Next offered 1989-90**
3-0-6

Surveys recent work in energy economics and management, paying particular attention to US energy situation. Develops analytical methods and stresses use of research tools and results in public- and private-sector decision making. Topics: international aspects of energy policy, domestic price controls, energy and the environment, demand modeling and management, new energy technologies, and interactions between energy sectors and the macroeconomy. Consult E. R. Berndt.

15.020 Competition in Telecommunications (A) (New)

Prereq.: 15.011 or equivalent
G (1)
3-0-6

Provides an introduction to the economics and technology of telecommunications markets, including markets for exchange and information services, cellular radio, long-distance services, and both carrier and customer equipment. The shifting roles of technology, Federal and state government policies, and business strategies in shaping these rapidly changing markets are studied, with particular emphasis on the roles of regulation and competition and the likely evolution of technology, public policy, and market structures over the next decade.
J. A. Hausman

15.024 Applied Economics for Managers

Prereq.: —
G (S)
3-0-6

Develops facility with concepts, language, and analysis tools of economics. Covers microeconomics, macroeconomics, and international trade and payments. Emphasizes integration of theory, data, and judgment in the analysis of corporate decisions and public policy, and in the assessment of changing US and international business environments. Restricted to Sloan Fellows.
H. D. Jacoby

15.031 Case Studies in Strategic Economic Analysis (A)

Prereq.: 15.011
G (1)
3-0-6

Analyzes public and corporate policy problems, with emphasis on approaching and solving complex problems. Students work through several actual policy problems during semester. Examples: a decision to import liquefied natural gas under a long-term contract, design of an optimal strategic stockpile of crude oil for the US, and financing of a new copper venture in a less developed country.
R. S. Pindyck

15.034 Applied Econometrics and Forecasting for Management (A)

Prereq.: 15.061 or 15.075
G (1, 2)
3-0-6

Designed for students interested in applied econometric methods and business forecasting. Emphasizes problems typically encountered in conducting empirical econometric research, in evaluating results and testing hypotheses, and in constructing forecasts. Requires term paper. Problem sets involve working with econometric models and the computer.
E. R. Berndt, T. M. Stoker

15.035 Pricing Strategy (A)

Prereq.: 15.011
G (2)
3-0-6

Draws on research in marketing and economics to present principles of profitable pricing and methods of applying them. Topics include pricing in oligopolies, implications of cost and demand dynamics, market segmentation, pricing new products, quantity discounts and nonlinear pricing, product-line pricing, and pricing in distribution channels. Antitrust and other legal issues discussed.
R. S. Pindyck, R. L. Schmalensee

15.036 Topics in Econometrics for Management (A) (New)

Prereq.: 15.034, 14.388 or equivalent
G (2)
3-0-6

The subject matter of this course changes from one year to the next, but is always focused on econometric and statistical issues that emerge when doing topical empirical research in economics, finance, marketing and/or strategy. Topics addressed include estimation and inference in discrete or categorical dependent variable models, confirmatory factor analysis, models with measurement error and multiple indicators, pooled cross-section and time series models, and forecasting techniques.
E. R. Berndt, T. M. Stoker

15.041 Research Seminar in Applied Economics

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

Discusses current research problems in applied economics. Topics vary from term to term. Designed primarily for doctoral students.
R. S. Pindyck, T. M. Stoker

Operations Research/Statistics

15.053 Introduction to Management Science

Prereq.: 18.02, *18.06*
U (1, 2) SD
4-0-8

15.058 Applied Mathematical Programming

Prereq.: 18.02, *18.06*
G (1, 2)
4-0-8

Introduces management science, emphasizing basic deterministic models and their optimization. Formulates and solves linear optimization models for management applications. Simplex method, duality theory, sensitivity analysis. Introduces networks, dynamic, integer, and nonlinear programming. Solving problems by computer and interpreting the results. 15.058 is more advanced than 15.062 and substitutes for it.
R. M. Freund, J. B. Orlin

15.059 Mathematical Programming Models and Applications (A)

Prereq.: 15.053 or 15.058 or 15.081J
G (1)
3-0-9

Extends the development of mathematical modeling techniques introduced in 15.058, emphasizing skills needed to perform model-based analysis. Covers practical applications of advanced mathematical programming modeling techniques, including network modeling, quadratic programming and applications, linear programming with uncertainty, and multiple objective programming, with case studies in production planning, vehicle routing, and strategic planning.
R. M. Freund

15.061 Decision Support Systems II

Prereq.: 18.01
G (1)
3-0-6

Introduces probability and statistical data analysis, emphasizing applications in management. Topics: basic probability, sampling and data collection, exploratory data analysis, inference and diagnostics for linear regression models, statistical computing and simulation. Restricted to graduate students in Sloan School of Management.
A. I. Barnett

15.062 Decision Support Systems III

Prereq.: 15.061
G (2)
3-0-6

Introduces management science concepts as applied to managerial problem solving. Emphasizes identifying problems, formulating models, assessing assumptions and data requirements, and evaluating model-based recommendations. Topics: decision analysis, simulation, linear programming, and network flows.
R. M. Freund, J. F. Shapiro

15.065 Decision Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Basic theory of decision making under uncertainty. Topics: decision trees, quantification of judgments and preferences, the value of information, Bayes theorem, the structuring of complex decisions, and multi-attributed utility theory.
G. M. Kaufman

15.067 Competitive Decision Making (A)

Prereq.: Permission of Instructor
G (2)
4-0-5

Problems of decision making in competitive and conflict situations, when behavior of competitors or adversaries affects decisions. Basic theoretical results in relevant fields. Participation in out-of-class negotiation exercises, simulating real competitive business situations, provides experience in making rapid but calculated decisions in situations characterized by a high degree of uncertainty and sophisticated competitors.
G. M. Kaufman

15.069 Seminar for Special Program in Management Science (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Seminar for individuals in Special Program in Management Science. Fall term involves outside speakers. Spring term is a project.
J. D. C. Little

15.071 Management Decision Support Models

Prereq.: —
G (S)
3-0-6

Model-based approach to modern managerial analysis. Introduces various techniques that support managerial decision making, including decision analysis, simulation, statistics, and linear programming. Emphasizes basic understanding and evaluation of techniques and their application, rather than technical expertise. Restricted to Sloan Fellows.
G. R. Bitran

15.072J Queues: Theory and Applications (A)

(Same subject as 6.264J)
Prereq.: 6.262 or 6.432 or 15.073J
G (2)
3-0-9

See description under subject 6.264J.
P. A. Humblet, J. Keilson, R. C. Larson

15.073J Introduction to Stochastic Processes (A)

(Same subject as 18.445J)
Prereq.: 18.313 or 18.440 or 6.041
G (1, 2)
3-0-9

See description under subject 18.445J.
Term 1: *M. Fygenson*
Term 2: *G. M. Ljung*

15.074 Mathematical Models and Policy Analysis (A)

Prereq.: 15.061 or 15.075
G (2)
3-0-6

Case-study method exploring strengths and weaknesses of mathematical models (especially those related to data analysis) that affect decision making of legislatures, corporations, courts, and regulatory agencies. Topics: carcinogenic hazards of various substances, deterrent effect of criminal sanctions, statistical evidence in job-discrimination proceedings, effective operation of mass-transit systems.
A. I. Barnett

15.075 Applied Statistics (A)

Prereq.: 18.440 or 6.041
G (1, 2)
3-0-6

Introduces statistical data analysis, concentrating on specific techniques used in management science. Topics: exploratory and graphical data analysis, smoothing, regression models and diagnostics, statistical inference for linear models, sampling and data collection. Open to qualified undergraduates.
A. I. Barnett

15.076J Statistical Modeling and Data Analysis (A)

(Same subject as 18.457J)
Prereq.: 15.075 or 18.443, 18.06
G (2) **Next offered 1989-90**
3-0-9

Data types and structures. Model formulation, fitting, simulation, and validation. Linear and nonlinear models: interpolation, forecasting, diagnostics, robustness, variable selection. Smoothing, data transformations, logistic and nonparametric regression. Illustrations on case material, with heavy use of statistical computing systems. Alternate years.
R. E. Welsch.

15.077 Statistical Methodology (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Designed for Ph.D. students. Topics covered: elementary data analyses, point and interval estimation, hypothesis testing, linear regression, PC-based statistical computation. Differs from 15.075 in emphasis on derivation of distribution theory needed to implement estimation and testing. Open to others only by permission of instructor. Consult R. E. Welsch.

15.078J Logistical and Transportation Planning Methods (A)

(Same subject as 1.203J, 6.281J, 11.526J, 13.665J, 16.76J)
Prereq.: 6.431, 15.075
G (1)
3-0-9

See description under subject 1.203J.
A. I. Barnett, R. C. Larson, A. R. Odoni, H. N. Psaraftis

15.079 Workshop in Applied Statistics

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Presentations by faculty, students, and guest speakers concerned with research in applied statistics, data analysis projects related to management, statistical consulting, and statistical computing. Discussions of recent literature, dealing with subjects of special interest to participants. Primarily for doctoral students.
R. E. Welsch

15.081J Introduction to Mathematical Programming (A)

(Same subject as 6.251J)
Prereq.: 18.06
G (1, 2)
3-0-9

See description under subject 6.251J.
R. M. Freund, R. G. Gallager

15.082 Network Optimization (A)

Prereq.: 15.081J
G (2)
3-0-9

Network models for industrial logistics systems, transportation systems, communication systems, and other applications. Emphasizes a rigorous treatment of algorithms and their efficiency — algorithms for shortest routes, maximum flows, minimum cost flows, traffic equilibrium, and network design. Implementation issues.
T. L. Magnanti, J. B. Orlin

15.083 Combinatorial Optimization (A)

Prereq.: 15.081J or Permission of Instructor
G (1)
3-0-9

Devoted to a theoretical and rigorous treatment of topics in integer programming and combinatorial optimization. Topics in combinatorial optimization include matching theory, matroid theory, computational complexity, design and analysis of heuristics. Topics in integer programming include formulations, branch and bound, Lagrangean techniques, cutting plane algorithms, group theoretic approaches, and Benders's decomposition.
J. B. Orlin, J. F. Shapiro

15.084J Nonlinear Programming (A)

(Same subject as 6.252J)
Prereq.: 18.06, *18.100*
G (2)
3-0-9

See description under subject 6.252J.
J. F. Shapiro, D. P. Bertsekas

15.089 Workshop in Operations Research

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Presentations by faculty, students, and guest speakers of ongoing research related to current issues in operations research. Typical topics: reports of research projects, proposed or in progress; and informal discussions of recent literature dealing with subjects of special interest to participants. Primarily for doctoral students.
T. L. Magnanti

15.099 Special Seminar in Operations Research (A)

Prereq.: 15.061, 15.062
G (1, 2)
Arr.

Current topics related to operations research not otherwise included in curriculum.
T. L. Magnanti

For additional related subjects in Statistics, see:

Civil Engineering: 1.03, 1.06, 1.15, 1.151, 1.152, 1.202J, 1.205, and 1.732

Electrical Engineering and Computer Science: 6.041, 6.231, 6.262, 6.264, 6.431, 6.432, and 6.435

Economics: 14.30, 14.31, 14.381, 14.382, 14.383, 14.384, 14.385, 14.386, and 14.388

Management: 15.034, 15.306, 15.572, and 15.832

Mathematics: 18.05, 18.175, 18.177, 18.313, 18.440, 18.441, 18.443, 18.445J, 18.446, 18.448, 18.454, 18.455, 18.456, 18.458, 18.465, and 18.466

See also: 2.061, 2.845, 5.72, 7.011, 8.044, 8.08, 10.816, 11.220, 11.222, 16.321, 16.37, 16.371, 17.842, 17.846, 17.850, 22.38, 22.40J, and HST 191

Health Care Management

15.121 Seminar in Health Management (A)

Prereq.: —
G (1)
3-0-6

15.122 Seminar in Health Management (A)

Prereq.: —
G (2)
3-0-6

Studies selected organizational and management issues facing managers of health services, health education, and health research institutions, as discussed by invited guests who are experienced managers. Primarily for graduate students with background or concentration in health management.
N. S. Stearns, E. B. Roberts

15.136J Health Technology (A)

(Same subject as HST 920J)
Prereq.: —
G (2)
3-0-6

Research seminar in the development, evaluation, and dissemination of medical technologies and practices. Strategies for management of basic and applied biomedical research. Communication channels for research results among researchers and from researchers to users. Analytic methods for evaluation of efficacy and social impact. Examines factors influencing commercial development of new health technology.
S. N. Finkelstein

15.141 Comparative Health Systems (A)

Prereq.: —
G (1)
3-0-6

Examines major issues facing health systems in the US and selected other countries from a variety of perspectives, including those of the physician, the manager, and the policy analyst. Considers cost, quality, access, and technology trade-offs as they affect government policy.
S. N. Finkelstein

15.144 Analytical Methods for Health Policy and Management (A)

Prereq.: —
G (2)
3-0-6

Applies analytical methods to health policy and management problems. Considers incidence, prevalence, cost, and other characteristics of disease and ill health having significant management or public-policy implications. Reviews public and private initiatives in disease control, prevention, and research.
S. N. Finkelstein

15.149 Special Studies in Health Management (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

For graduate students who desire to do advanced work or research on a health management problem not specifically covered elsewhere. Readings, conferences, fieldwork, and reports.
E. B. Roberts, S. N. Finkelstein

International Management

15.215 International Dimensions of Management

Prereq.: —
G (2)
3-0-6

Theory and practice of international business, emphasizing strategy selection and implementation in response to the changing international environment. Examines some of the distinctive management problems that arise in international firms.
D. R. Lessard

15.221 International Business Management (A)

Prereq.: —
G (1, 2)
3-0-6

Basic course on the international dimensions of management. Examines the changing patterns of international business, environmental factors (state, comparative advantage, industry) and the strategic tasks of the firm, and the challenges involved in managing across borders.
D. E. Westney, R. M. Locke

15.222 Strategy in a Global Context (A)

Prereq.: 15.221 or Permission of Instructor
G (2)
3-0-6

About corporate strategies that are successful against international competitors. Develops sense of how individual multinational enterprises succeed. Emphasizes organization-strategy match, and a general management framework that allows consideration of strategic and organizational choices in multinational firms. Consult D. R. Lessard.

15.223 Assessing Foreign Business Environments

Prereq.: 15.221
G (1)
3-0-6

Focuses on the role of national environments in multinational business. Students are exposed to the analytic methods and tools needed to assess the political, economic, and technology-related dynamics of foreign business settings. Examines the role of the host government as a player and then considers what particular kinds of firms should do in particular nations over time.
R. M. Locke

15.227 International Technology Transfer (A)

Prereq.: —
G (2)
3-0-6

This course focuses on the transborder movement of technology, highlighting the role of the multinational firm as the chief purveyor of international technology flows. Particular emphasis is given to the forces that facilitate and constrain international technology transfer (e.g., export controls), along with discussion of the varying perspectives of the suppliers and recipients of technology. Consult D. R. Lessard.

15.229 Special Seminar in International Management (A)

Prereq.: 15.221
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to international business not otherwise included in curriculum.
D. R. Lessard

15.232 The Firm and the Business Environment in Japan (A)

Prereq.: —
G (1)
3-0-6

Examines how Japanese firms and their business environments have been viewed from Western management perspectives; the nature of the Japanese business environment (financial, political, human, technological, social, and cultural resources); and the internal organization and strategic processes of Japanese firms.
D. E. Westney

History and Environment

15.268 Readings in Power and Responsibility (A)

Prereq.: Permission of Instructor
G (2) [P/F]
3-0-6

Studies managerial power and responsibility in relation to today's world. Examines conflicts between power and moral responsibility, the value-complexes that underlie modern Western society, and the major political and economic stances available to leadership in coping with current problems. Restricted to Sloan Fellows.
W. F. Bottiglia

Communication

15.280 Communication for Managers

Prereq.: —
G (1, 2)
2-0-4

Writing and speaking skills necessary to a career in management. Students learn communication strategies and methods through discussion of principles, examples, and cases. Many short written and oral assignments, some coordinated with other subjects. Restricted to first-year Sloan School of Management graduate students.
J. Yates, A. Golden

15.281 Advanced Managerial Communication (A)

Prereq.: 15.280
G (1)
3-0-6

Builds on managerial writing and speaking skills developed in 15.280. Introduces more advanced oral and interpersonal communication skills important to managers, including running and contributing productively to meetings, listening, and being interviewed by news media. Also provides instruction and practice in writing longer reports and giving longer oral presentations for a business audience, generally in conjunction with an outside project for another subject.
J. Yates

Organization Studies

15.301 Managerial Psychology Laboratory

Prereq.: —
U (1, 2) LAB
2-6-4

Core subject for students majoring in management science. Surveys individual and social psychology and organization theory interpreted in the context of the managerial environment. Laboratory involves projects of an applied nature in behavioral science. Emphasizes use of behavioral science research methods to test hypotheses concerning organizational behavior.
T. J. Allen, J. S. Carroll

15.304 Complex Organizations

Prereq.: 15.301
U (2)
3-0-6

Examines structures, processes, values, and working practices of various forms of social organization. Sociological and anthropological writings provide framework for describing deviancy, control, ritual, authority, decision making, and socialization in organizational settings. Combines field observations, interviews, and participation in a given social organization, with readings drawn from the ethnographic literature on culture and subculture in America.
J. Van Maanen

15.306 Behavioral Science Research Methods

Prereq.: —
U (1)
3-0-9

Introduces methods of behavioral science research. General strategy of behavioral research (quantitative vs qualitative analysis, hypothesis formulation) and research design (purposes, variance control, control of extraneous variables, use of control groups, randomized designs, factorial designs). Specific techniques of various designs (questionnaire construction, sampling, interviews, systematic observation). Organization and development of research project. Information: J. S. Carroll.

15.311 Managerial Behavior in Organizations

Prereq.: —
G (1, 2)
3-0-6

Examines interpersonal and human side of both public and private enterprise. Emphasizes managerial applications of social-science concepts and research findings. Uses experiential learning modes and case analyses, as well as lectures and discussions. Class materials cover both micro concerns (i.e., individuals and small groups), and macro issues (i.e., organizational interrelations, culture, and learning). Primarily for first-year Sloan master's students in fall term, others only by permission of instructor.
J. Van Maanen

15.312 Managerial Decision Making (A)

Prereq.: 15.301 or 15.311
G (1)
3-0-6

Examines individual managerial behavior within organizations, with emphasis on cognitive processes in judgment and choice. Includes judgment under uncertainty, biases and corrective procedures, risk perception, models of judgment and choice, decision aids, and problem structuring techniques. Students without stated prerequisites may enroll with permission of instructor.
D. N. Kleinmuntz

15.313 Interpersonal Dynamics and the Management of Groups (A)

Prereq.: 15.301 or 15.311
G (2)
3-0-6

Examines basic concepts of how people relate to each other and how groups work from both a psychological and sociological perspective. Through lectures, discussion, roleplays, videotaping, group exercises, and written assignments, students learn not only the concepts but also how to improve their own communication and group membership skills. Topics include performance appraisal, negotiation, team decision making and meeting management. Students without stated prerequisites may enroll with permission of instructor.
D. L. Ancona

15.314 Organization Design (A)

Prereq.: 15.301 or 15.311
G (2)
3-0-6

Examines the character and characteristics of effective organizations. Includes designing organization structures, managing change, organization environment relationships. Classes use lectures, seminars, practice cases, films, and some team projects. Students without stated prerequisites may enroll with permission of instructor.
R. J. Thomas

15.317 Comparative Study of Organizations (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Examines management of organizations and organizational processes in various parts of the world. Special focus on highly industrialized societies. Designed for advanced master's and doctoral students.
D. E. Westney

15.322 Organizational Psychology and Sociology (A)

Prereq.: Permission of Instructor
G (1) [P/F]
3-0-6

Analyzes — through lectures, discussions, and class exercises — management of human resources in industry. Restricted to Sloan Fellows.
J. Van Maanen, E. H. Schein

15.337 Sociology of Work and Organizations (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Reviews key concepts and research findings from sociology that illuminate the nature of work in industrial societies, how organizations emerge and change, and how managerial processes influence individual and organizational action. Practice in the use of fieldwork methods for the study of work and organization in both public and private sectors. Designed for advanced master's and doctoral students. Alternate years.
J. Van Maanen

15.339 Social Psychology of Work and Organizations (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

Reviews key concepts and research findings from social psychology that illuminate the nature of work, functioning of organizations, and managerial process. Issues in use of social psychological methods for studying work and organizations, both in public and private sector. Designed for advanced master's and doctoral students. Alternate years.
J. S. Carroll

15.341 Seminar in Behavioral Sciences

Prereq.: —
G (2)
3-0-6

Develops basic concepts for understanding individual, group, and organizational behavior through critical analysis of important works in the field. Areas covered: cognitive, affective, change, control, input, throughput, output, and structural processes. Emphasizes use of behavioral science concepts for stimulating new and useful management science research and the application of behavioral science results to typical management problems. Restricted to doctoral candidates in the Sloan School of Management.
J. Van Maanen

15.345 Doctoral Seminar in Organization Studies I (A)

Prereq.: Permission of Instructor
G (1)
2-0-7

15.346 Doctoral Seminar in Organization Studies II (A)

Prereq.: 15.345
G (2)
2-0-7

Seminar covering the basic fields of social psychology, individual psychology, and sociology and organization theory, for purposes of preparing the doctoral candidate for his or her doctoral examinations. Basic concepts, theories, and research methods serve as focus for the seminar. Restricted to doctoral candidates. Information: J. S. Carroll.

15.347 Doctoral Seminar in Research Methods I (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Introduces the process of social research, emphasizing the conceptualization of research choices to maximize validity, relevance, and benefit-costs comparisons. Includes research design (experiments, quasi-experiments) and specific measurement techniques (questionnaires, interviews, observation).
J. S. Carroll

15.348 Doctoral Seminar in Research Methods II (A)

Prereq.: 15.347
G (2) [P/F]
4-0-8

Practice of social science research. Students learn to handle specific research problems through intensive analysis of published research papers, a series of written exercises, and group term projects based on a common database provided for the class. Emphasizes logic of data analysis and role of conceptualization in the research process.
L. L. Bailyn

15.349 Personal Issues in the Management of Human Resources (A)

Prereq.: —
G (2)
2-0-7

Explores assumptions underlying organizational career procedures and consequences of these procedures for employees. Considers implications of changes in individual lifestyles and in values surrounding work and success on management of human resources in organizations.
L. L. Bailyn

M.I.T. ANNUAL CATALOGUES AND BULLETINS
1988-89

05
OF
06

Management of Technology and Innovation

15.351 Introduction to Technological Innovation Management (A)

Prereq.: —
G (1, 2)
3-0-6

Introduction to the sources of technological innovation, economics of innovation, protection of innovation rights, capturing benefit from innovation, organizing to manage the innovation process, new ventures.
E. A. von Hippel, M. A. Rappa

15.355 Managing Technological Innovation (A)

Prereq.: —
G (1)
2-0-4

Managerial perspectives on development and consequences of technological innovations in product and manufacturing process. Issues relating to managing scientists and engineers as individuals, in teams, and in large organizations. Interfaces between R&D function and marketing and production. Technology planning and strategy approaches, including new venture structures for business development and diversification. Restricted to Sloan Fellows only.
E. B. Roberts

15.361 Managing Professionals (A)

Prereq.: Permission of Instructor
G (1, S)
3-0-6

Examines human side of management of professionals through application of behavioral science research findings. Topics: supervising/motivating professional employees; career orientations; effective conflict management; group creativity/decision making; managing product teams; group aging; critical roles for innovation; organizational structure/communication. Emphasizes professional individuals and groups. (Summer term is restricted to members of the Management of Technology Program.)
R. Katz, D. L. Ancona

15.365J Manufacturing/Technology Interface (A)

(Same subject as 3.565J, 13.685J)
Prereq.: Permission of Instructor
G (2)
3-0-6

Focus on the management of process innovation. Economic and other influences on manufacturing process change. Interactions between research, development, and engineering activities, and manufacturing operations. Transfer of new product developments into manufacturing.
J. M. Utterback

15.367 Market/Technology Interface (A) (Revised Unit)

Prereq.: *15.810* or *15.812* or *15.814*
G (1)
3-0-3

User role in new product innovation; efficient linking of user and manufacturer new product development efforts; market research techniques for novel industrial products and for "lead" user identification. Primarily for members of the Management of Technology Program.
E. A. von Hippel

15.368J Cases and Issues in Engineering Management (A) (New)

(Same subject as 6.942J)
Prereq.: —
G (2)
3-0-6

See description under subject 6.942J.
T. H. Lee

15.369 Corporate Strategies for Managing Research, Development, and Engineering (A)

Prereq.: 15.351 or 15.355 or 15.361
G (2)
2-0-7

Strategic issues in managing research, development, and engineering. Single overall theme chosen each year from wide range of topics, including such subjects as corporate research laboratories, new venture organizations, and integration of RD & E into corporate strategy. Lecture sessions by faculty and by invited speakers from government and industry. Independent study and preparation of reports by individual students or teams of students. Permission of instructor required.
E. B. Roberts

15.371 The R&D Process: Communication and Problem Solving (A)

Prereq.: 15.311 or 15.351 or 15.361
G (1)
3-0-6

Examines the fundamental processes of research and development. Contrasts basic science with technology. Presents recent research on the structuring of organizations to accomplish research and development goals. Looks at factors influencing technical communication patterns and technology transfer.
T. J. Allen

15.375 New Enterprises (A)

Prereq.: Permission of Instructor
G (1, 2)
2-1-6

Develops detailed plan for launching a new technical venture by each student. Lectures provide information needed to succeed at this task. Topics: organization and management of ventures, patents and other means of new product protection, obtaining venture capital, research partnerships.
R. W. Olive

15.379 Seminar in Management of Technology (A) (New)

Prereq.: 15.361, 15.515
G (1)
3-0-3

Current practices and issues in the Management of Technology are analyzed and discussed by experienced leaders from industry and government. Examines different approaches to managing the technology function within a broad organizational context, in seminar discussions and in the field. Restricted to Management of Technology Program students.
M. L. Gnecco

Finance

15.410 Accounting and Finance II

Prereq.: 15.515
G (2)
2-0-4

Surveys and analyzes financial problems facing managers, including theoretical introduction to financial institutions, financial instruments, and capital markets. Topics: functions and operations of capital markets, theory of efficient markets, portfolio and valuation theory, capital budgeting and investment decision making, firm's cost of capital, long-term financing instruments and financing decisions, dividend policy and capital structure. Restricted to graduate students in Sloan School of Management.
J. C. Cox

15.411 Financial Management (A)

Prereq.: 15.511, 15.024, 15.071
G (1)
3-0-6

Surveys what an organization invests in and how much it invests, where and how funds for investment are obtained, and how financial institutions and financial markets operate. Topics: capital budgeting and investment decision making, functions and operations of the capital markets, valuation theory, long-term financial instruments and financing decisions, capital structure and dividend policy. Restricted to Sloan Fellows. Information: S. C. Myers.

15.412 Financial Management II (A)

Prereq.: 15.501 or 15.515
G (1, 2)
4-0-8

Content similar to 15.410, but coverage deeper and more extensive. Primarily for students not concentrating in finance.
J. E. Parsons

15.413 Topics in Corporate Financial Management (A)

Prereq.: 15.410 or 15.411 or 15.412
G (1, 2)
3-0-6

Extends and applies topics and concepts covered in 15.410, 15.411, 15.412. Covers financial planning, leasing and project financing, mergers, pensions, and new approaches to corporate investment and financing decisions. Information: R. C. Merton.

15.415 Finance Theory (A)

Prereq.: 15.011, 15.515
G (1, 2)
6-0-9

Core theory of capital markets and corporate finance. Topics: functions and operations of capital markets, analysis of consumption-investment decisions of investors, diversification and portfolio selection, valuation theory and equilibrium pricing of risky assets, theory of efficient markets, and investment and financing decisions of firms. Theoretical foundation for further study and practical applications. Required for students concentrating in finance.
R. C. Merton, R. Mehra

15.416 Introduction to Financial Economics (A) (New)

Prereq.: 14.121, 14.122
G (1, 2)
3-0-6

Foundations of modern financial economics; individuals' consumption and portfolio decisions under uncertainty and implications for the valuation of securities. Topics include: expected utility theory; stochastic dominance; portfolio frontiers; mutual fund separation; asset pricing model; arbitrage pricing theory; Arrow-Debreu economies; dynamic spanning options; rational expectations; financial signaling. Primarily for doctoral students in accounting, economics, and finance.
C-F. Huang

15.418 Taxation and Business Management (A)

Prereq.: 15.410 or 15.412 or 15.415
G (1, 2)
3-0-6

Analyzes effect of taxation on conduct of business. Concentrates on major decisions where taxes impinge on the firm or its managers; concern with both theory and relevant empirical evidence. Topics covered: the "double-taxation" of dividends, the effect of capital gains taxation, tax incentives, compensation planning, the effect of taxation on effort, alternatives to income taxation. Information: S. C. Myers.

15.419 Finance for International Managers (A)

Prereq.: 15.012, 15.410 or 15.411 or 15.412
G (2)
3-0-6

Analyzes decisions of firms operating internationally, emphasizing interaction of financial considerations with operating strategy and tactics. Topics: implications of fluctuating exchange rates; differing fiscal regimes; segmented and distorted capital markets; political risks for investment, financing, contracting, financial logistics, measurement and control of performance. Examples from industrialized and developing countries. Primarily for students not concentrating in finance. Credit not given for both 15.419 and 15.436. Consult J. E. Parsons.

15.432 Capital Markets and Financial Institutions (A)

Prereq.: 15.415
G (2)
3-0-6

Role and functioning of the capital and money markets as a device for the allocation of resources, the channeling of investable funds, and the reallocation of risk. Function of financial intermediaries operating in these markets. Information: S. C. Myers.

15.433 Security Prices (A)

Prereq.: 15.415
G (2)
3-0-6

Studies behavior of security prices and returns. Empirical work on efficient markets hypothesis and capital asset pricing models. Applications to portfolio management and corporate finance. Requires empirical term project. Information: S. C. Myers.

15.434 Capital Investment Decisions (A)

Prereq.: 15.415
G (2)
3-0-6

Theory and practice of capital investment decisions. Approaches to estimating risk and adjusting for it. Applications of option pricing and new approaches to valuation. Managerial incentive problems in investment decisions. The market for corporate control.
D. Scharfstein

15.435 Corporate Financing Decisions (A)

Prereq.: 15.415
G (1)
3-0-6

Theory and practice of corporate financing decisions. Empirical work on debt and dividend policy; agency cost and signaling models; issue procedures and investment banking; leasing, project financing, convertible securities.
J. E. Parsons

15.436 International Managerial Finance (A)

Prereq.: 15.012, 15.415
G (1)
3-0-6

Examines factors that distinguish international from domestic setting, including volatile currencies, differing fiscal regimes, segmented and distorted capital markets, and cross-border risks. Analyzes implications for valuation theory and applications, including investment and financing decisions, financial logistics, foreign exchange risk management, and performance measurement. Primarily for students concentrating in finance. Credit not given for both 15.436 and 15.419.
D. R. Lessard

15.437 Options and Futures Markets (A)

Prereq.: 15.415
G (1, 2)
3-0-6

Develops option pricing theory. Applies theory to valuation of put and call options, loan guarantees, and corporate liabilities. Empirical tests of the models and investment strategies. Futures markets, emphasizing financial futures and their uses.
J. C. Cox

15.438 Investment Banking and Markets (A)

Prereq.: 15.415
G (1)
3-0-6

Surveys the international investment banking industry and the financial markets and intermediaries dealt with by the industry. Description of trading and hedging techniques. Analysis of new financial products and procedures.
R. C. Merton

15.440J Advanced Financial Economics: I (A) (Revised Unit)

(Same subject as 14.490J)
Prereq.: 15.416
G (1)
3-0-9

Covers advanced topics in the theory of financial markets with a focus on continuous time models. Topics include multiperiod securities markets and martingales; pricing of contingent securities such as options; optimal consumption and portfolio problems of an individual; dynamic equilibrium theory and the Intertemporal Capital Asset Pricing Model; and term structure of interest rates. This subject is primarily for doctoral students in accounting, economics, and finance.
C-F. Huang

15.441J Advanced Financial Economics: II (A) (New)

(Same subject as 14.491J)
Prereq.: 15.416
G (2)
3-0-9

Surveys selected topics in current advanced research in corporate finance. Primary focus is upon problems of information and game theory as they apply to corporate financing decisions, market micro-structures (including the takeover markets), the design of efficient and optimal financial contracts, organization and accounting structure design, and asset valuation. This subject is primarily for doctoral students in accounting, economics, and finance.
J. E. Parsons

15.443 Research Seminar in Finance (A)

(15.441)
Prereq.: 15.415
G (1, 2) [P/F]
3-0-6

Presentation and analysis of original research in finance. For Sloan School doctoral candidates in finance. Others admitted only by permission of instructor.
D. Scharfstein

15.449 Special Seminar in Finance (A)

Prereq.: 15.410 or 15.412 or 15.415
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to finance not otherwise included in curriculum.
S. C. Myers

Accounting

15.501 Introductory Financial Accounting

Prereq.: —
U (1, 2)
3-0-6

Introduces basic concepts and techniques of collecting, processing, and reporting financial information generated by a business. Emphasizes basic financial accounting concepts and methods of financial analysis.
R. Bhushan

15.511 Financial and Management Accounting

Prereq.: —
G (S)
3-0-6

Studies basic concepts of financial accounting and the accounting principles underlying financial statements. Viewpoint is that of the users of accounting information (especially managers) rather than the preparer (the accountant). Restricted to Sloan Fellows. Information: P. Healy.

15.515 Accounting and Finance I

Prereq.: —
G (1)
3-0-6

Introduces basic concepts and techniques of collecting, processing, and reporting financial information generated by a business. Examines financial valuation issues in accounting. Introduces methods of financial analyses, with goal of enabling students to understand and use corporate financial statements. Restricted to Sloan School of Management graduate students.
P. Healy, P. C. O'Brien

15.516 Introductory Financial Accounting (A except XV)

Prereq.: Permission of Instructor
G (1, 2)
3-0-6

Meets with 15.501.
R. Bhushan

15.521 Management Accounting and Control (A)

Prereq.: 15.501 or 15.511 or 15.515 or 15.516
G (1, 2)
3-0-6

Examines management accounting and related analytical methodologies for decision making and control in profit-directed organizations. Budgetary control systems for planning, coordinating, and monitoring the performance of a business and its functional components; methods for controlling capital expenditures and working capital funds. Principles of measurement. Develops framework for assessing behavioral dimensions of control system design; impact of different managerial styles on motivation and performance in an organization.
F. J. Fabozzi

15.525 Corporate Financial Accounting (A)

Prereq.: 15.501 or 15.511 or 15.515 or 15.516
G (1, 2)
3-0-6

Examination of corporate financial accounting policy, fundamental issues, and emerging shifts in the financial accounting area. Advanced analysis and interpretation of financial statements and pronouncements of various agencies concerned with financial accounting (FASB, SEC, etc.).
P. C. O'Brien

15.532 Planning and Control Systems (A)

Prereq.: 15.501 or 15.515 or 15.516
G (2)
3-0-6

Development of a framework for analyzing an organization and its environment, to provide basis for designing information systems and procedures to support the management of strategic development and operating performance. Goal formation and direction setting, long-range planning, budgeting and monitoring systems. Design of responsibility accounting systems in relation to strategy; problems of multidimensional measurement. Coordination of responsibility centers and transfer pricing mechanisms. Content of 15.521 relevant but not required. Information: P. Healy.

15.535 Financial Statement Analysis (A)

Prereq.: 15.515, 15.410 or 15.411 or 15.412 or 15.415
G (1)
3-0-6

Techniques for financial statement analysis and uses of analysis in a decision-making context. Applications include lending decisions, risk analysis, and equity valuation for merger and divestiture purposes. 15.525 recommended.
P. Healy

15.539 Special Seminar in Accounting and Control (A)

Prereq.: 15.515
G (1)
Arr.

Designed primarily for doctoral students in accounting and related fields. The reading list consists of accounting research papers. The objective of the course is to introduce research topics, methodologies, and developments in accounting. Information: P. C. O'Brien.

15.549 Workshop in Accounting and Control

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Presentations by faculty, doctoral students, and guest speakers of ongoing research related to current issues in financial and managerial accounting and in planning and control systems in organizations. Topics: reports of research projects (proposed or in progress) and discussions of recent literature in the area. Selects specific topics geared to interests of participants. Restricted to doctoral students.
P. C. O'Brien

Management Information Systems

15.560 Decision Support Systems I

Prereq.: —
G (1)
2-0-4

Introductory concepts in computer hardware, software, and management information systems. Familiarization with and use of computer resources and software available at MIT, which may be useful in subsequent subjects, research, or thesis work. Restricted to graduate students in Sloan School of Management.
C. F. Kemerer, T. W. Malone

15.562 Principles of Management Information Systems (A)

Prereq.: 1.00 or 2.10 or 6.001 or 15.560 or programming experience
G (1, 2)
3-0-6

Introductory examination of issues related to effective use of computer-based information systems in organizations. Topics: technology (computer systems and databases), frameworks for analyzing need for information systems, designing and implementing systems for effective use, management of the information system life cycle. Represents a condensation of 15.564, 15.565, and 15.568; credit not given for both 15.562 and 15.568. Limited enrollment.
H-M. D. Toong

15.564 Management Information Technology I (A)

Prereq.: 1.00 or 2.10 or 6.001 or 15.560 or programming experience
G (1, 2)
4-0-8

Intense coverage of modern information technology and its operational and strategic applications. Technology topics include computer architecture; 1st-, 2nd-, 3rd-, and 4th-generation programming languages; translators and compilers; table processing; searching and sorting; database systems; and operating systems. Student projects, using machine language, assembly language, C programming language, SQL database language, and the UNIX Shell command language.
S. E. Madnick, R. Davis

15.565 Management Information Technology II (A)

Prereq.: 15.564
G (1, 2)
3-0-6

Provides background in and a framework for integrating the concepts essential to analysis and development of computer-based information systems: data management software techniques, computer-based design aids, and concepts relevant to managing information as a corporate asset. Develops student's understanding of computer technology to enable its use in new and creative ways in an organization. Discusses examples of the implementation and use of actual management information systems.
J. C. Henderson, S. E. Madnick

15.568 Management Information Systems (A)

Prereq.: 15.564, *15.565*
G (1, 2)
3-0-6

Concepts, frameworks, tools, techniques, and processes that assist management in its interaction with and direction of computer-based information systems today. Discusses major transaction processing systems of the firm, as well as those systems used primarily for managerial information. Emphasizes managerial point of view and organizational issues involved in managing a firm's information resources. Credit not given for both 15.562 and 15.568.
J. F. Rockart, T. W. Malone

15.569 Advanced Decision Support Systems (A)

Prereq.: 15.562 or 15.568
G (1, 2)
3-0-6

Focuses on issues and techniques involved in development of computer-based systems designed to support manager's decision-making and problem-solving processes. Topics: assessment of the technology available, development of frameworks and techniques with which to analyze and organize key decisions and a manager's decision-making process, and discussion of the design and implementation of such systems in ongoing organizations. Lectures, cases, projects, and analysis of existing decision support systems.
Information: J. C. Henderson.

15.571 Advanced Computer Systems (A)

Prereq.: 15.564
G (2)
3-0-6

Issues and trends in operating systems with OS responsibilities to provide services and management of the resources (storage, tasks, devices, and data). Trends and issues both in mainframes and microsystems (multiprogramming, demand paging, virtual machines, multiprocessors, systems performance, and the advent of networked OS's) as part of study of several OS's. Management of technologists appears throughout. Assumes programming beyond BASIC, and involves significant reading which is provided.
R. A. MacKinnon

15.572 Systems Simulation (A)

Prereq.: 15.061, 15.560
G (2)
3-0-6

Introduces discrete simulation and model building methodology, using high-speed digital computers. Focus on event-oriented as opposed to continuous systems. Emphasizes simulation language and model building. Considers issues of proper experimental design, statistical analysis of results, effects of random number generation techniques, and validation. Some discussion of typical applications. Information: S. E. Madnick.

15.574 Information Systems, Data Structures, and Databases (A)

Prereq.: —
G (1)
3-0-9

Introduction to a range of topics in the area of information systems, with an emphasis on performance issues and on the underlying theory. Computer language and architecture topics include machine language, assemblers, compilers, and operating systems. Data structure topics include abstract data types, sorting, searching, memory management, and other selected topics. Database management topics include a study of relational, network, and hierarchical models.
J. C. Henderson, J. B. Orlin

15.579 Special Seminar in Management Information Systems (A)

Prereq.: 15.564
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to management information systems not otherwise included in curriculum.
S. E. Madnick

15.581 Information Systems and Law (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Examines interlocking technological and legal issues that arise in the operation of computer-based information systems in society. Emphasizes, in class discussions and in term projects, interdisciplinary definition, analysis, and solution of specific problems. Continuing effort toward improving and integrating technical, social, and legal concepts of information. Topics: security and privacy in databanks, computer infringement of copyright, protection of proprietary rights in software, jurimetrics.
J. A. Meldman

15.599 Workshop in Management Information Systems

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Presentations by faculty, doctoral students, and guest speakers of ongoing research relating to current issues in management information systems, as well as discussions of key research papers in the field. Determines specific topics by the interest of participants and by new and important directions in information systems. Background readings and active participation by students expected. Primarily for doctoral students.
S. E. Madnick

Law

15.600J Negotiation in Engineering Systems (New — Context Subject)

(Same subject as 13.95J)
Prereq.: —
U (1)
3-3-6

Teaches societal, economic, legal, and environmental issues pertinent to the successful negotiation of large engineering systems. Presents the skills, processes, and tools required for the synthesis of effective outcomes in complex negotiations. Up to three real contexts are studied in detail. Each week, one session focuses on teaching the elements of negotiation management, another on contextual analysis, and the third on a simulated negotiation among students.
J. D. Nyhart, H. N. Psaraftis

15.601 The American Legal System

Prereq.: 14.01 or 14.02 or 15.001
U (1) HASS
3-0-6

Meets with 15.611.
J. A. Meldman

15.611 The American Legal System (A)

Prereq.: 14.01 or 14.02 or 15.001
G (1)
3-0-6

General intensive introduction to law and the American legal system. Analyzes components and operation of the legal process in context of specific legal problems. Examines judicial reasoning and development of legal doctrine. Topics: torts, contracts, criminal and constitutional law, trial procedure and evidence, administrative law, scope of the judicial process, and the relationships between state and Federal law. Extensive reading of case law together with textual materials and legal essays. Research projects involving use of a law library.
J. A. Meldman

15.615 The Manager's Legal Function (A)

Prereq.: —
G (1, 2)
3-0-9

Provides a basic understanding of legal issues that corporations meet during their existence. Follows one firm throughout its life — from birth to bankruptcy, first as a breakaway from an established high-tech firm, then proceeding through initial funding efforts, establishment of its capital and corporate structure, and through problems in labor, trade secrets, contracts and antitrust, product liability, and resolution of transnational and domestic business disputes.
J. D. Nyhart, J. A. Lachman

15.635 International Law and Regulatory Order (A)

Prereq.: —
G (2)
3-0-6

Jurisdiction, sources, and nature of international law. Issues basic to private-sector managers, including international economic law, extension of US domestic regulatory policies beyond US territory, and the problems of obtaining consistency among nations' regulation of transborder business. Emergence of international regulation of transportation, communications, trade, ocean use, finance, food and health standards, and multinational corporations.
J. D. Nyhart

15.640 Seminar on Government-Business Relations (A)

Prereq.: —
G (2)
3-0-6

Emphasizes process through which law is made at congressional, executive, and administrative agency levels, and defines key points at which business executives can shape legislation and policy. Discusses ways to resolve conflicts between government and business. Weekly sessions divided between outside speakers from both sectors and classroom materials and discussion. Requires term paper. Meets with 15.645.
J. D. Nyhart

15.645 Government and the Management of Technology (A)

Prereq.: —
G (2)
3-0-6

The changing role of government in shaping and directing the management of technology in the civilian sector of the economy. Principal themes: rationales, processes, and mechanisms of government involvement; promotion and regulation of technological development and use by government; and industrial policy in the US and other countries. Illustrative case studies: protection of individual property, R&D policy, environmental regulation, administrative law. Meets with 15.640.
G. Heaton, J. D. Nyhart

15.649 Special Seminar in Law (A)

Prereq.: —
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to law not otherwise included in curriculum.
J. D. Nyhart, J. A. Lachman

15.650J Chemicals in the Environment: Policy and Management

(Same subject as 11.363J, TPP 54J)
Prereq.: —
G (2)
3-0-6

See description under subject 11.363J.
J. D. Nyhart, J. R. Ehrenfeld, L. E. Susskind

Industrial Relations and Human Resource Management

15.60J AIDS: Scientific Challenge and Human Challenge (New — Context Subject)

(Same subject as 7.00J)
Prereq.: —
U (1)
3-0-3

AIDS presents a challenge for many disciplines. As a public health and policy issue, it is a challenge to our ethical beliefs and to the taxpayer. As a scientific problem, it is a test of our ability to find methods of cure and prevention. As an international issue, it threatens economic and social progress in the developing world. Lectures illuminate AIDS as a challenge in molecular biology, epidemiology, economics, management, public policy, and other professions. Ten lectures: subject ends November 21. Limited enrollment.
M. P. Rowe, D. Baltimore

15.660 Industrial Relations and Human Resource Management

Prereq.: —
G (2)
2-0-4

15.662 Industrial Relations and Human Resource Management (A)

Prereq.: —
G (1)
3-0-6

15.663 Collective Bargaining and Employment Policies

Prereq.: —
G (1)
3-0-6

Introduces industrial relations and human resource management at level of the firm. Explores role of firm in its larger industrial relations systems. Examines effects of the environment on human resource management strategies. Assesses strategies against their effects on the firm, its employees, labor organizations, and public policies. Uses collective bargaining game to demonstrate dynamics of negotiations and conflict resolutions. 15.660 restricted to Sloan School of Management graduate students. 15.662 restricted to Sloan Fellows. Coverage in 15.662 and 15.663 deeper and more extensive.
15.660: *T. A. Kochan*
15.662: *R. B. McKersie*
15.663: *T. A. Kochan*

15.664 Management of Human Resources (A)

Prereq.: —
G (1)
2-0-7

Seminar covering various topics in labor economics and human resources. Topics include career patterns in organizations, public employment policy, impact of technical change, discrimination and affirmative action, wage determination, training policy, and unionization.
P. Osterman

15.665 Power and Negotiation (A)

Prereq.: —
G (1)
3-0-6

Provides understanding of the theory and processes of negotiation as practiced in a variety of settings. Designed for relevance to the broad spectrum of bargaining problems faced by the manager and professional. Allows students opportunity to develop negotiation skills experientially and to understand negotiation in useful analytical frameworks. Emphasizes simulations, exercises, role playing, and cases.
R. B. McKersie, M. P. Rowe

15.666 Negotiation and Conflict Management (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Explores theory and processes of negotiation within an employment context. Covers conflict management as a first party and as a third party (third-party skills include helping others deal directly with their conflicts, mediation, investigation, arbitration, helping the system itself to change as a result of a dispute). Special cases: abrasiveness, dangerousness, meanness, whistleblowing, ethics. Simulations of difficult situations: hiring, firing, drug use, etc. Complementary to 15.665.
M. P. Rowe

15.671J Labor Economics I (A)

(Same subject as 14.671J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

See description under subject 14.671J.
M. J. Piore

15.672J Labor Economics II (A)

(Same subject as 14.672J)
Prereq.: 14.04
G (2)
3-0-6

See description under subject 14.672J.
H. S. Farber

15.673J Labor, Public Policy, and Income Distribution (A) (Revised Unit)

(Same subject as 14.673J)
Prereq.: 14.64 or 15.633
G (1)
3-0-9

See description under subject 14.673J.
H. S. Farber, R. Blank

15.674J Comparative Systems of Industrial Relations and Human Resource Development (A)

(Same subject as 14.674J, STS 505J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

International and comparative analysis of industrial relations systems and systems of human resource development. Concentrates on an examination of selected issues involving the nature and functions of labor and management organization in different contexts, role of the state in establishing procedures and shaping the substance of industrial relations, manpower and economic growth in the context of comparative systems of human resource development, worker participation in management, and other topics.
M. J. Piore, R. J. Thomas

15.675J Earnings (A) (Revised Content and Unit)

(Same subject as 14.675J)
Prereq.: 15.672J or Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

See description under subject 14.675J. Information: H. S. Farber.

15.676 Industrial Relations Theory and Research Seminar (A)

Prereq.: Permission of Instructor
G (2)
2-0-7

Historical evolution and assessment of research in industrial relations. Introduces doctoral students to the field and explores where their research interests fit within the broader field. First part compares the normative assumptions, theories, and methodologies used by economists, historians, sociologists, psychologists, and legal scholars from the latter 19th century to the present. Final portion explores strategies for advancing research on topics of current interest to participants.
T. A. Kochan

15.691J Research Seminar in Industrial Relations (A)

(Same subject as 14.691J)
Prereq.: —
G (1)
3-0-6

15.692J Research Seminar in Industrial Relations (A)

(Same subject as 14.692J)
Prereq.: —
G (2)
3-0-6

Discusses important areas for research in industrial relations; frameworks for research, research techniques, and methodological problems. Centered mainly on staff research and the thesis research of advanced graduate students and invited guests. Information: R. B. McKersie.

15.699 Special Seminar in Industrial Relations (A)

Prereq.: 15.660 or 15.662 or 15.663
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to industrial relations and human resource management not otherwise included in curriculum.
T. A. Kochan

Operations Management

15.760 Introduction to Operations Management

Prereq.: 15.061, 15.062
G (2)
2-0-4

15.761 Operations Management (A)

Prereq.: 15.053 or 15.062, 6.041 or 15.061
G (2)
3-0-6

Introduces students to problems and analysis related to the design, planning, control, and improvement of manufacturing and service operations. Includes process analysis, project analysis, forecasting, materials management, production planning and scheduling, quality management, computer-aided manufacturing technologies, capacity and facilities planning, and operations strategy. 15.760 restricted to graduate students in Sloan School of Management. Coverage is deeper and more extensive in 15.761.
C. H. Fine, L. Li, L. M. Wein

15.763 The Practice of Operations Management (A)

Prereq.: 15.760 or 15.761
G (1)
3-0-6

Provides an opportunity to learn how to diagnose complex problems, structure relevant solutions to them, and deal with issues of implementing the solutions. Case analyses and projects in local manufacturing and service organizations extend understanding of and ability to deal with operating management situations. Emphasizes integrative approach, using methodologies drawn from operations research, management information systems, and organization design.
S. C. Graves

15.764 The Theory of Operations Management (A)

Prereq.: 15.081J, 6.431, 15.761
G (2)
3-0-6

Focus on theoretical work for studying operations planning and control problems. Topics vary from year to year, and will include inventory theory, sequencing theory, aggregate production planning, production scheduling, multistage production/distribution systems, performance evaluation, and flexible manufacturing systems.
S. C. Graves

15.765 The Operating Manager (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Develops operating skills of a manager through case analyses and discussions. Cases drawn primarily from manufacturing situations and are designed to improve the manager's ability to analyze an operating situation, define the operating task, and accomplish that task. Primary emphasis is on accomplishment — policy implementation, changes in operations, etc. Information: G. R. Bitran.

15.767 Industrial Project Evaluation (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Subject organized to familiarize student with methodologies and applications related to Project Evaluation. Several actual industrial and governmental projects analyzed. Methodologies related to capital budgeting, cost-benefit analysis, financial management, strategic planning, and operations management covered. Information: G. R. Bitran.

15.768 Operations Management in the Service Industry (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Explores the difference between service and manufacturing operations, and the degree of distinct management skills and tools required. Analyzes cases selected from variety of service operations. Guest speakers from specific service industries discuss essence of managing those operations.
G. R. Bitran

15.769 Manufacturing Policy (A)

Prereq.: 15.760 or 15.761 or Permission of Instructor
G (1, 2)
3-0-6

Provides framework for analyzing strategic issues in manufacturing. Analyzes relationships between manufacturing managers and their suppliers, customers, competitors, superiors, and hourly workers. Also covers the interface between manufacturing and marketing, engineering, quality, purchasing, finance, and accounting. Devotes a moderate amount of time to how the Japanese do it.
C. H. Fine

15.770J Transportation and Logistics Analysis (A)

(Same subject as 1.208J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 1.208J.
S. C. Graves, Y. Sheffi

15.778 Service Industry Operations (A)

Prereq.: Permission of Instructor
G (1)
2-0-4

Examines the special problems of designing, producing, and delivering services (as opposed to physical goods) and explores the different management tasks faced in various types of service firms. The primary (though not exclusive) focus of the course is on operations management, including the relationship between operating decisions and company strategy. Restricted to Sloan Fellows.
G. R. Bitran

15.779 Manufacturing Management (A)

Prereq.: Permission of Instructor
G (1)
2-0-4

Provides framework for analyzing strategic issues in manufacturing. Analyzes relationships between manufacturing managers and their suppliers, customers, competitors, superiors, and hourly workers. Also covers the interface between manufacturing and marketing, engineering, quality, purchasing, finance, and accounting. Devotes a moderate amount of time to how the Japanese do it. Similar in content to 15.769. Restricted to Sloan Fellows.
C. H. Fine

15.795 Seminar in Operations Management (A)

Prereq.: 15.760 or 15.761
G (1, 2)
3-0-6

Topics vary from year to year. Typical examples from past years: manufacturing strategy, managing quality control.
C. H. Fine

15.799 Workshop in Operations Management

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Presentations by faculty, doctoral students, and guest speakers of ongoing research relating to current issues in operations management. Topics: reports of research projects (proposed or in progress) and informal discussions of recent literature dealing with subjects of special interest to participants. Primarily for doctoral students. Consult S. C. Graves.

Marketing

15.810 Introduction to Marketing

Prereq.: 15.061, 15.062
G (2)
2-0-4

Introduces concepts, challenges, and techniques necessary to manage the marketing function. Topics: marketing research, consumer behavior, new product development, advertising strategy, promotion, personal selling, distribution, and pricing. Lectures, guest speakers. Problem assignments or cases. Restricted to graduate students in Sloan School of Management. Others see 15.812. Consult D. L. Marlino.

15.811 Marketing (A)

Prereq.: 15.071, 15.511
G (1)
3-0-6

Analyzes elements of marketing strategy that can be utilized by business, governmental, and social organizations to meet the needs of their clientele. Topics: product development, advertising, selling, and pricing. Reviews contributions of management science in providing new techniques for solution of marketing problems. Restricted to Sloan Fellows.
S. H. Star

15.812 Marketing Management (A)

Prereq.: 15.061 or 6.041 or 14.30 or 18.05
G (1)
3-0-6

Similar content to 15.810, but coverage is deeper and more extensive. Primarily for non-Sloan School graduate students and undergraduate students.
J. R. Hauser

15.814 Marketing Management (A)

Prereq.: 15.061 or equivalent
G (1)
3-0-6

Similar in content to 15.812. Restricted to Management of Technology students.
J. R. Hauser

15.820 Advanced Marketing Management (A)

Prereq.: 15.810 or 15.812
G (2)
2-0-4

Concentrates on marketing strategy. Guest speakers, case studies, and team participation in marketing strategy game. Primarily for Sloan School of Management graduate students; others admitted by permission of instructor.
D. L. Marlino

15.824 Marketing Communications (A)

Prereq.: 15.810 or 15.812
G (1)
3-0-6

Focus on management problems that arise when attempting to communicate with and influence a market or other public in an organization's environment through advertising and related mass media and promotion campaigns. Lectures, guest speakers, case discussions, projects.
D. L. Marlino

15.825 Marketing Models (A)

Prereq.: 15.810, 15.812, or Permission of Instructor
G (1)
3-0-6

Basic modeling approaches. Models for specific decision areas: price, promotion, advertising, distribution, and sales force. Integrative models; the marketing mix, new products. Emphasizes decision support systems.
J. D. C. Little

15.828 New Product Development (A)

Prereq.: 15.810 or 15.812
G (2)
3-0-6

Identifies new market opportunities. Designs "core benefits" of a new product having high potential. Designs physical product and marketing mix to fulfill the "core benefits." Testing, launching, and managing the new product. Develops theory, measurement, and models to manage this process. Requires term project.
J. R. Hauser

15.832 Measurement for Management (A)

Prereq.: 15.061
G (2)
3-0-6

Focus on methods for collecting and analyzing behavioral data applicable to a variety of measurement problems in management. Research and sampling design. Develops questionnaires, scaling and psychometric methods for measuring perceptions, attitudes, and preferences. Statistical techniques for analyzing these types of data.
F. R. Kardes

15.834 Marketing Strategy (A)

Prereq.: 15.810 or 15.812
G (2)
3-0-6

Examines marketing aspects of strategy formulation. Studies market phenomena that are foundations of strategy. Analyzes management science models for brand, product line, strategic-business unit, and corporate marketing strategy. Lectures, cases, guest speakers.
G. L. Urban

15.836 Managing Consumer and Trade Promotions (A)

Prereq.: 15.810 or 15.812
G (1)
3-0-6

Focus on problems that arise in allocating, evaluating, and managing expenditures for promotional inducements, including coupons, premiums, rebates, price-off packs, special offers to retailers, short-term price reductions. Lectures, discussions, projects.
Information: J. R. Hauser.

15.838 Research Seminar in Marketing (A)

Prereq.: 15.810 or 15.812
G (1, 2)
3-0-6

Seminar on current marketing literature and current research interests of faculty and students. Topics such as the theory of consumer behavior, competitive strategy, marketing experimentation, and the development of behavioral models. Consult D. L. Marlino.

15.839 Workshop in Marketing

Prereq.: Permission of Instructor
G (1, 2) [P/F]
Arr.

Presentations by faculty, doctoral students, and guest speakers of ongoing research relating to current issues in marketing. Topics: reports of research projects (proposed or in progress) and informal discussions of recent literature dealing with subjects of special interest to participants. Primarily for doctoral students.
J. R. Hauser

System Dynamics

15.852 Principles of Dynamic Systems I

Prereq.: —
U (1, 2) SD
3-0-9

15.872 Principles of Dynamic Systems I (A)

Prereq.: —
G (1, 2)
3-0-9

Introductory course in *system dynamics,* a powerful computer simulation technique for modeling physical, human, and other systems. Aids in the analysis of complex issues such as technological change, AIDS, corporate strategy, ecological change, economic turmoil, and student burnout. Learn to deal with situations where policies are defeated by unanticipated reactions and side effects. Emphasizes a mix of computer models, role-playing games, and case studies. Hands-on experience with a variety of computer simulation models and software.
J. D. Sterman

15.873 Principles of Dynamic Systems II (A)

Prereq.: 15.872 or 15.874
G (2) **Not to be offered 1989-90**
3-0-9

Continues philosophy and methods of 15.872, with purpose of expanding student's ability to build computer simulation models and analyze behavior arising from complex dynamic feedback systems. Topics: translating qualitative observations on real systems into quantitative models; methods for relating system structure to system behavior; common errors in model construction and policy design. Alternate years.
J. D. Sterman

15.874 System Dynamics for Business Policy (A)

Prereq.: —
G (1)
3-0-9

Why do so many business strategies fail? Introduction to system dynamics modeling applied to corporate strategy. Uses a mixture of simulation models, role-playing games, and case studies to develop principles for successful management of complex strategies in a dynamic world. Case studies of successful strategy design using system dynamics. Considers strategic issues such as business cycles, market growth and stagnation, the diffusion of new technologies, the misuse of forecasts, and the rationality of managerial decision making.
J. D. Sterman

15.875 Applications of System Dynamics (A)

Prereq.: 15.872 or 15.874
G (2) **Next offered 1989-90**
3-0-6

Project-based subject, applying methods of system dynamics to real corporate problems. Class divided into groups that act as consultants to local corporations. Meetings with corporate managers and staff to obtain information for model construction; instructor provides advice and guidance on model formulation and testing. Final report on work done and recommendations. Alternate years.
J. D. Sterman

15.878 Economic Dynamics (A)

Prereq.: 15.872 or 15.874
G (1)
3-0-6

Introduces system dynamics modeling of economic systems, focusing on the dynamics of modern industrial economies. Combines lectures, exercises, and a term project on subject of student's choice. Topics: economic cycles, inflation and unemployment, periods of depression, capital investment and monetary policy, and resource depletion.
J. D. Sterman, P. M. Senge

15.879 Seminar in System Dynamics Policy Analysis (A)

Prereq.: 15.872 or 15.874
G (2) **Next offered 1989-90**
3-0-6

Research seminar focusing on development of student projects to illuminate important aspects of policy analysis based on computer simulation models. Each exercise designed to give students direct experience with some problem in policy analysis and the issues involved in resolving or handling that problem. Topics vary from year to year. Typical examples from past years: problems in designing policies based on forecasts, economic policy, energy policy, corporate strategy. Alternate years.
J. D. Sterman

Corporate Strategy and Policy

15.930 Strategic Management

Prereq.: —
G (1)
2-0-4

15.931 Strategic Management (A)

Prereq.: —
G (1)
3-0-6

Deals with approaches to strategic management problems affecting all facets of the enterprise. Discussions, cases, field studies, and readings trace strategy practice, methodology, and theory. Focus on both strategic formulation and implementation. 15.930 useful as a broad introduction to the corporate strategy field and is restricted to Sloan School of Management graduate students. Coverage is deeper and more extensive in 15.931 and is restricted to Sloan Fellows.
15.930: *M. A. Cusumano, M. Horwitch, M. S. Scott Morton, N. Venkatraman*
15.931: *A. C. Hax, M. Horwitch*

15.932 Technology Strategy (A)

Prereq.: 15.930 or 15.931 or Permission of Instructor
G (1)
3-0-6

Considers key aspects of the emerging technology-strategy relationship in the large corporation from different perspectives, including the individual firm, an entire industry, the industrial policy of a nation, cross-country comparisons, and cross-industry comparisons. Uses conceptual readings, empirical studies, case studies, student field studies, and invited outside speakers.
M. Horwitch

15.933 Advanced Strategic Management (A)

Prereq.: 15.930 or 15.931 or Permission of Instructor
G (1, 2)
3-0-6

Focuses on some important issues in strategic management. Builds on foundation provided by the basic subject in strategic management (15.930 or 15.931) and applies perspectives in new, relevant, and challenging directions.
A. C. Hax

15.934 Research Seminar in Corporate Strategy (A)

Prereq.: 15.930 or 15.931
G (1, 2)
3-0-6

Seminar built around published theoretical and empirical research in corporate strategy. Students share leadership of seminar, using journal articles focusing on the study of particular strategic issues or problems. Articles drawing on theory and/or methodology may come from current literature in economics, the behavioral sciences, or management science. Articles and topics change each term.
N. Venkatraman

15.936 Applied Corporate Analysis (A)

Prereq.: *15.412* or *15.415, 15.761, 15.812*
G (1)
3-0-6

Provides practice in identifying important management issues, making reasoned judgments about priorities, and defending choice of issues and priorities. Students assume various roles as managers, analysts, and board members in class sessions simulating top management and board meetings. Visits to operating and corporate executives. Limited to 20.
W. F. Pounds

15.937 Game-Theoretic Corporate Strategy (A) (New)

Prereq.: 15.011
G (2)
3-0-6

Develops fundamental concepts relating to strategic interactions in static and dynamic settings, emphasizing the role of reputation formation, asymmetric information, bluffing, signaling, incentives, and adverse selection. The game-theoretic approach is applied to case studies illustrating implicit collusion, entry deterrence, takeovers, collective bargaining, and executive compensation, among others.
G. Saloner

15.939 Advanced Topics in Policy and Strategy (A)

Prereq.: 15.930 or 15.931
G (1, 2)
Arr.

Directed research and study of advanced topics in corporate policy and strategy, as well as public policy relating to the private sector. Primarily for doctoral students in Management; others admitted by permission of instructor. Information: N. Venkatraman.

15.940 Japanese Technology Management: Strategy and Implementation

Prereq.: Permission of Instructor
G (2)
3-0-6

Examines how leading Japanese firms have implemented strategies for technology transfer, product-process development, and related operations, from WWII to the present. Industries covered are automobiles, consumer electronics (especially VTRs), computer hardware and software engineering, and machine tools (FMS). Japanese companies considered include Toyota, Nissan, Honda, Mazda, Sony, Japan Victor, Matsushita, NEC, Hitachi, Fujitsu, Toshiba, Yamazaki, and Hitachi Seiki. Also, comparisons to US firms and industries.
M. A. Cusumano

15.941 Managing the Development Effort (A)

Prereq.: 11.431 or 15.410 or 15.412 or 15.415
G (2)
3-0-6

Case studies of real estate development companies illustrate management and theory concepts. Course topics include: strategic planning, organization design, succession, styles and skills, delegation, motivation and rewards, learning, information technology, and ethics. Students are required to participate in field projects.
G. Schuck

Special Studies

15.951 Special Studies in Management

Prereq.: —
U (1, 2)
Arr.

Special tutorial arrangement with a faculty member for guided reading, research, laboratory, or teaching experience.
J. A. Meldman

15.952-15.959 Special Seminars in Management (New)

Prereq.: —
U (1, 2)
Arr.

Opportunity for group study by undergraduate students on current topics related to management not otherwise included in curriculum. Consult Undergraduate Program headquarters.

15.961 Special Studies in Management (A)

Prereq.: —
G (1, 2)
Arr.

For graduate students who desire to do advanced work or to carry out some special investigation of a management problem not specifically covered elsewhere and not qualifying as a thesis. Readings, conferences, laboratory and fieldwork, and reports. Consult Department headquarters.

15.962-15.969 Special Seminars in Management (A)

Prereq.: —
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to management not otherwise included in curriculum. Consult Department headquarters.

15.977 Seminar in Management

Prereq.: —
G (1)
2-0-1

Investigates effective management through informal meetings with executives representing a range of industries and functions in both public and private sectors. Examines managerial philosophies, practical problems of management, personal career paths, and enables students to develop skill in careful listening and the art of asking questions. Restricted to Sloan School of Management graduate students.
D. A. Weber

15.978 Seminar in Management (A)

Prereq.: 15.511
G (1)
3-0-6

Fundamental economic, financial, organizational, and administrative relationships analyzed and discussed by experienced leaders in business, labor, and public administration. Examines managerial philosophies and practices in the field and in seminar discussions. Restricted to Sloan Fellows.
A. F. White

Course 16

Aeronautics and Astronautics

16.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in aeronautics and astronautics. For further information, contact W. R. Markey, Departmental Coordinator.

16.001 Unified Engineering I

Prereq.: 8.01, *18.03*
U (1) SD
5-2-5

16.002 Unified Engineering II

Prereq.: 8.01, *18.03*
U (1)
5-2-5

16.001: Requires simultaneous registration with 16.002. 16.002: Presents principles and methods of engineering in a format of lecture, recitation, and design. Basic disciplines presented with the unifying themes: forces and their interaction with solids and fluids; energy and energy transfer; systems control and information handling. Topics: mechanics of solids and fluids, forces, stresses, geometry of motion, conservation of mass and momentum, properties of solids, and fluids; principles of measurement and control; temperature, thermodynamic properties, and states. First law of thermodynamics; conservation of energy. Applications include particle dynamics, stress and strain in simple structures; low-speed flow; lift, drag, and thrust; loads and design criteria in aerospace systems. Laboratory exposure to empirical methods in engineering; illustration of principles and practice. Design of a typical aircraft or spacecraft element. Provides a sound basis for a wide variety of careers in engineering.
E. F. Crawley, E. M. Greitzer, R. J. Hansman, J. E. McCune, H. Y. Wachman

16.003 Unified Engineering III

Prereq.: 16.001, 16.002
U (2)
5-2-5

16.004 Unified Engineering IV

Prereq.: 16.001, 16.002
U (2)
5-2-5

16.003: Requires simultaneous registration with 16.004. 16.004: Presents sound, basic concepts, principles, and methods of engineering, emphasizing unified presentation of disciplines, by application to high-technology devices and aerospace systems. Topics: dynamics of rigid and deformable bodies; center of mass, rigid body motion, inertia tensor; second law of thermodynamics, entropy, irreversibility; high-speed flow, shock waves, stresses in fluids, heat transfer; interaction between component devices, signal flow, feedback, and stability in control. Applications include strain energy and principles in structural analysis, failure modes in structures, fracture, fatigue, plasticity; beams, plates, shafts; airfoil theory, flow over bodies, channel flow, boundary layers; thermal cycles, chemical-to-thermal conversion, aircraft and rocket engines. Techniques presented for analysis and optimization of systems. Experiments in mechanics, strength of materials, subsonic and supersonic flows, rockets and turbo machinery; system dynamics and control, analog simulation of control system. Design and evaluation of an aircraft or spacecraft component.
D. L. Akin, E. F. Crawley, R. J. Hansman, J. E. McCune, H. Y. Wachman

16.005 Introduction to Aerospace Engineering

Prereq.: —
U (2)
3-1-5

Presents a broad view of steps involved in developing aerospace systems from preliminary design to production. Drafting techniques, weight estimation, aerodynamic analysis, control, structural design, cost estimating, manufacturing processes, certification, and service engineering discussed in the context of an aerospace vehicle that each student designs. Recommended for freshmen.
D. L. Akin, N. D. Ham, R. W. Simpson

16.008 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

16.02 Aerodynamics

Prereq.: 16.004 or 2.20 or 1.05
U (1, 2)
4-0-8

Kinematics and dynamics of fluids in aerodynamic applications. Vorticity, circulation, Biot-Savart induction. Lift, drag, thrust, and the momemtum theorem. Energy conservation. Boundary layers, skin friction, heat transfer. Unsteady flow. Supersonic aerodynamics. Methods of characteristics. Distribution of singularities. Interference and images. Panel methods. Airfoils, Kutta condition. Wings, performance, subsonic flow. Turbulence, separation and stall.
J. E. McCune, S. E. Widnall

16.025 Numerical Fluid Dynamics (A)

Prereq.: 16.02 or 16.06, *18.075* or *18.085* or *18.086*
G (1)
3-0-9

Modeling and solution of flow field partial differential equations by discretization (finite difference) methods. Physical concepts and descriptions for viscous/inviscid, one-/two-dimensional, steady/unsteady incompressible and compressible flow. Numerical simulation topics include accuracy, stability, convergence, iterative, and time-evolution techniques. Applications to external and internal flows. Computer assignments.
J. R. Baron, M. B. Giles

16.026 Advanced Computational Fluid Dynamics (A)

Prereq.: 16.025 or 2.274
G (2)
3-0-9

Computational methods for compressible inviscid and viscous flow. Euler and Navier-Stokes equations in general nonorthogonal, curvilinear coordinates, using finite-difference, finite-volume, and finite-element methods. Coordinate system generation. Draws applications from internal and external flow problems in aerospace vehicles. Assignments requiring use of digital computer.
E. M. Murman, M. B. Giles

16.028 Special Topics in Computational Fluid Dynamics (A)

Prereq.: 16.026
G (1)
1-0-2

A seminar for students specializing in computational fluid dynamics. Topics vary with interests of the class, but are drawn from emerging discretization techniques (finite-volume, spectral, vortex methods), boundary condition treatment, solution methods (direct solvers, multigrid, Alternating Direction Implicit), advanced computer architecture, and CFD applications.
M. B. Giles

16.035 Fluid Mechanics (A)

Prereq.: 16.02 or 16.06, 18.075 or 18.085
G (1)
4-0-8

Prepares students for graduate study in fluid mechanics and aerodynamics, and for some of its applications in science and engineering. Discusses the basic concepts of continuous fluid mechanics and how they underlie the properties of particular flow fields, such as potential and rotational constant density inviscid and viscous flows. Shows applications to flow past airfoils and wings, vortex flows, and some geophysical flows. Special attention to boundary layers and their transition to turbulence. Any undergraduate subject in fluid mechanics or aerodynamics accepted for 16.02.
L. Trilling, M. T. Landahl

16.04 Aerodynamics of Flight Vehicles

Prereq.: 16.02
U (1)
3-1-8

Aerodynamic analysis and computational techniques for flight vehicles, building on basic concepts from 16.02. Laminar and turbulent-boundary layers. Transition and separation criteria. High-lift wing-flap systems. Subsonic cruise aerodynamics for wing-body-tail configurations. Other examples and topics drawn from the current and previous years' 16.84 design projects.
E. M. Murman, M. Drela

16.041 Aerodynamics of Viscous Fluids — Boundary-Layer Approximation (A)

Prereq.: 16.035
G (2)
3-0-9

Boundary layers as rational approximations to the solutions of exact equations of fluid motion. Physical parameters influencing laminar and turbulent aerodynamic flows and transition. Effects of compressibility and heat condition. Influence of boundary layers on outer potential flow and appropriate numerical solution techniques. Numerical exercises require familiarity with FORTRAN or similar language.
M. Drela

16.042 Heat and Mass Transfer (A)

Prereq.: 16.041
G (1)
3-0-9

Fundamentals of heat and mass transfer applied to aerodynamics, space, and propulsion problems. Conduction heat transfer, thermal stresses resulting from nonuniform temperature distribution. Free convection and buoyancy effects. Forced convection with laminar and turbulent boundary layers. Regenerative and recuperative heat exchangers. Mass transfer with blowing and suction. Transpiration and film cooling. Boundary layers with ablation. Radiative heat transfer and space radiators. Permission of instructor for students who have not had 16.041.
Staff

16.044J Turbulence and Random Processes in Fluid Mechanics (A)

(Same subject as 12.865J)
Prereq.: 2.20 or *16.035*
G (1)
4-0-8

Development of descriptions of random fields. Response of systems and fields to random inputs, with examples from waves. Sources of turbulence, hydrodynamic stability, equations, spectra, equilibrium, and decay. Shear flow turbulence, turbulent boundary layers. Methods of observation, measurement, and analysis. Discusses problems of current interest.
M. T. Landahl, S. E. Widnall

16.051 Supersonic and Hypersonic Gas Dynamics (A)

Prereq.: 16.035
G (2)
4-0-8

Fundamental concepts and modeling for hypersonic flight. Equations of motion and boundary conditions for perfect real gas and for real fluid mechanics. Governing parameters for energy levels, scales, and limits for continuum flow. Strong shock waves, blasts, and self similarity. Hypersonic small-disturbance theory, blunt bodies, thin shear, entropy, and boundary layers. Viscous-inviscid interactions; real gas contributions. Approximate and numerical methods.
J. R. Baron, L. Trilling, M. T. Landahl

16.052 Real Gas Dynamics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Gas behavior appropriate to motion at high speed and energy. Equilibrium-limit gas modeling. Relaxation coupling of fluid mechanics with translational, chemical, plasma, and radiative phenomena. Wave propagation, dispersion, shocks, similarity, surface-interface coupling. Applications of approximate and numerical methods to flight vehicles, test facilities, and gas-dynamic lasers.
J. R. Baron

16.055 Unsteady Fluid Mechanics (A)

Prereq.: 16.035
G (1) **Next offered 1989-90**
3-0-9

Fluid mechanics of fixed airfoils, wings, bodies, and cascades in unsteady potential flows; or moving airfoils, wings, bodies, and cascades in a uniform stream. Methods (analytical and numerical) for predicting the pressure on unsteadily moving bodies in subsonic, transonic, and supersonic flow. A limited discussion of viscous effects, boundary layers, aerodynamic noise generation, flow instability, and separation introduced where appropriate. Alternate years.
M. T. Landahl

16.056 Special Topics in Unsteady Separated Flows (A)

Prereq.: 16.035, 16.041
G (1) **Not to be offered 1989-90**
3-0-6

Develops understanding of basic phenomena underlying the physics of unsteady separated flows. Based upon a wide review of experimental, theoretical, and CFD results. Topics include steady 2-D separation, dynamic stall, diffuser stall, vortex shedding, unsteady flows in turbo machinery, leading-edge vortices, and vortex bursting. Alternate years.
M. B. Giles

16.06 Molecular Gas Dynamics of Space and Reentry

Prereq.: 16.004 or 2.40 with either 2.20 or 1.05
U (1)
4-0-8

Elements of gas dynamics relevant to orbiting flight and atmospheric entry of space vehicles. Molecular and convective effects. Drag and heat transfer. Discussion is based on kinetic theory of gases and on statistical mechanics. Leads to understanding of real gas effects, including rates of dissociation and ionization, and radiative heat transfer. Gas-surface interactions. Application to performance of space vehicles.
L. Trilling, H. Y. Wachman

16.065 Spacecraft-Environmental Interaction (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

Reviews fundamentals of plasma physics appropriate to the ionosphere/magnetosphere. Spacecraft charging at geostationary orbit; absolute and differential charging; methods of control; electron beams, plasma guns, and electrostatic noise. Environmental interactions at low-earth orbit; effects, wakes, neutral gas flow, Alfven wings. Topics of current interest, high-voltage large-space structures in low-earth orbit, atomic oxygen effects, electrodynamics of tethers; wave generation by the space station. Alternate years.
D. E. Hastings, H. Y. Wachman

16.07 Aerodynamics of Wings and Bodies (A)

Prereq.: 16.035, 18.075 or 18.085
G (2) **Next offered 1989-90**
3-0-9

Aerodynamic loading on wings and bodies. Lift vs circulation. Kutta and viscosity. Large and low aspect-ratio wings. Induced drag, wave drag, form drag, skin friction. General theorems. Lifting surfaces in sub- and supersonic flow. 3-D features. Bodies of revolution. Cross-flow concepts. Source and panel methods. Area rule. Wing-body combinations. Separation and stall. Transonic flow. Alternate years.
J. E. McCune, S. E. Widnall

16.081J Principles of Acoustics (A)

(Same subject as 2.060J, 13.81J)
Prereq.: 2.03J or 16.004, 18.075
G (1)
3-0-9

See description under subject 2.060J.
P. Leehey, R. H. Lyon

16.15 Applied Analytical Dynamics (New)

Prereq.: 16.004 or equivalent
G (1) **Next offered 1989-90**
3-0-9

Reviews fundamental concepts in dynamics of mechanical systems. Treats kinematics in some depth, including recursive kinematics of tree-connected multibody structures. Introduces selected methods of analytical dynamics; Alembert's principle and its generalizations, Lagrange's equations (for constrained and unconstrained systems), Hamilton's equations. The syllabus is driven by application to examples; robot manipulators, multibody spacecraft (both rigid and flexible bodies), nonholonomically constrained systems such as a unicycle. The focus is on engineering modeling rather than theoretical rigor. Alternate years.
A. H. von Flotow

16.16 Introduction to Flight Vehicle Dynamics

Prereq.: 16.004 or 1.05 or 2.20; 18.03
U (1)
3-0-9

Theory of flight; airfoils, lift, drag, and applied aerodynamics. Root locus, and similar control techniques. Airplane performance, engine characteristics. Introduces stability and control of airplanes. Equations of motion. Static stability, neutral points, and maneuver points. Effect of CG movement. Linearized equations of motion and stability derivatives. Characteristic longitudinal and lateral motions. Elements of handling qualities. Effects of variation of aerodynamic parameters on airplane stability and control.
R. V. Ramnath

16.17 Advanced Flight Dynamics and Control (A)

Prereq.: 16.16
G (2)
3-0-9

Brief review of applied aerodynamics. Wing, fuselage, and tail contributions. Power, compressibility, and aeroelastic effects. Modern approach to aircraft stability and control. Motion along steep trajectories, reentry dynamics, and stability of a shuttle vehicle. Human pilot models and autopilots. Variable flight conditions. VTOL transition. Sensitivity to parameter variations in variable systems. Motion at high angle-of-attack, roll coupling, and other nonlinear flight regimes.
R. V. Ramnath

16.18 Spacecraft Dynamics and Control (A)

Prereq.: 16.004, 16.30
G (2) **Next offered 1989-90**
3-0-9

Reviews rigid body kinematics and dynamics for small and large rotations. Reviews attitude sensors and actuators and the attitude guidance and control problem. Open-loop stability analyses are developed for a variety of equilibrium conditions; spinners, dual spinners, gravity gradient equilibria. Active control is applied to the same examples: bang-bang control for thrusters, linear multivariable control for coupled roll/yaw motion, active nutation damping. Effects of fuel slosh and structural flexibility covered briefly.
A. von Flotow

16.20 Structural Mechanics

Prereq.: 16.004 or 2.01
U (1, 2)
5-0-7

Applies solid mechanics to analysis of high-technology structures. Plane stress, plane strain problems. Bending, shear, torsion of rods, and thin-wall beams. Introduces energy principles and computer-oriented structural analysis, such as matrix and finite-element methods. Applications to statically indeterminate structures and solid continua. Buckling of column and stability phenomena. Theories and modes of structural failure. Principles in optimal structural design.
P. A. Lagace, J. Dugundji

16.21 Plates, Stability, and Thermoelasticity (A)

Prereq.: 16.20
G (2) **Next offered 1989-90**
3-0-9

Analyzes anisotropic plates typical of laminated composite structures. Coupling of and duality in bending and stretching of plates, transverse shear effect. Large deflections of plates. Theory of stability of structures and applications to buckling of plates. Equations of thermal elasticity. Heat transfer and thermal stress analysis for supersonic and hypersonic aircraft. Alternate years.
J. Dugundji

16.22 Shell Structures (A)

Prereq.: 16.20
G (1) **Not to be offered 1989-90**
3-0-9

Elements of tensor analysis. General formulation of elasticity in curvilinear coordinates. Introduction to differential geometry. Development of shell equations in tensor form. Membrane behavior of thin shells. Bending behavior of thin shells. Shallow shells, shells of revolution, edge zones. Alternate years.
J. W. Mar, J. Dugundji

16.24 Plasticity, Viscoelasticity, and Creep (A)

Prereq.: 16.20
G (2) **Not to be offered 1989-90**
3-0-9

Plastic stress-strain relations of materials. Yield conditions, flow rules and strain-hardening rules. Limit and shakedown analysis. Characterization of linear viscoelastic behaviors, creep compliance and relaxation modulus, discrete-element models, spectrum and dynamic representations. Viscoelastic stress analyses, correspondence principle and integral equation solutions. Nonlinear creep laws. Structural analyses in presence of creep. Creep buckling. See 2.073 and consult advisor.
T. H. H. Pian

16.251 Structural Design for Longevity (A)

Prereq.: 16.20
G (1) **Not to be offered 1989-90**
3-0-9

Longevity is the most difficult of all the structural integrity requirements for aerospace vehicles. Examines the many aspects of longevity such as frequency of loads, fatigue of materials, growth of cracks, safe-life philosophy, fail-safe philosophy, damage tolerance, stress concentrations, scatter factors, testing. Introduces linear elastic fracture mechanics and its use. Emphasizes application of theory to practice. A portion devoted to study of case histories.
J. W. Mar

16.261J Structural Mechanics in Nuclear Power Technology (A)

(Same subject as 1.56J, 2.084J, 3.82J, 13.14J, 22.314J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 22.314J.
O. Buyukozturk, M. S. Kazami

16.27 Finite-Element Method (A)

Prereq.: 16.20
G (1)
3-0-9

Formulation of finite-element method, through use of variational principles for structural mechanics and continuum mechanics, assumed displacement and assumed stress models. Tools in numerical analyses, interpolation, and integration. Problems treated include plane stress and plane strain, plate bending and three-dimensional solids. Emphasizes practical ways of constructing and assembling the element matrices and methods of solving large systems of algebraic equations by modern computers. Students required to carry out actual solutions using the digital computer.
T. H. H. Pian

16.28 Advanced Finite-Element Method (A)

Prereq.: 16.27
G (2) **Not to be offered 1989-90**
3-0-9

Generalized variational principles in solid mechanics and related finite-element models. Incremental formulations of elastic-plastic, large deflection, and creep analyses. Superposition of analytical and finite-element solutions. Applications to shells of revolution, fracture mechanics, finite element in time, and nonstructural problems. Current development of finite-element method. Alternate years.
T. H. H. Pian

16.291 Manufacturing with Advanced Composite Materials

Prereq.: —
U (1)
1-3-2

Introduces the various methods used to manufacture parts made of advanced composite materials. Revolves around laboratory sessions in the Technology Laboratory for Advanced Composites. Students gain hands-on experience by using various laboratory techniques to fabricate and test graphite/epoxy specimens. Lectures supplement laboratory sessions with background information on the nature of composites, curing, composite machining, secondary bonding, and the testing of composites.
J. Dugundji

16.292 Mechanics of Filamentary Composite Materials (A)

Prereq.: 16.20
G (2)
3-0-9

Studies the behavior of filamentary composite materials composed of boron, graphite, glass, and Kevlar fibers embedded in a matrix. Material properties of fibers and matrices. Micromechanics, anisotropic elasticity, tensor notation, and Classical Laminated Plate Theory. Also includes failure analysis, buckling, sandwich construction, thermal and moisture stresses, and interlaminar stresses. Design concepts and cost-effective applications.
P. A. Lagace

16.293 Advanced Topics in Filamentary Composite Materials (A)

Prereq.: 16.292
G (1) **Next offered 1989-90**
3-0-9

Generalized study of the anisotropic properties of composite laminates. Failure modes, fracture theories/correlations, damage tolerance, fatigue, interlaminar stresses, environmental effects. Reviews current problems in the applications of composite materials in the aerospace and automotive industry. Guest lecturers share their experiences. Permission of instructor for students without 16.292.
J. W. Mar, P. A. Lagace, J. Dugundji

16.30 Principles of Automatic Control

Prereq.: 18.03
U (1, 2)
3-1-8

Fundamental physical and analytical principles used in the design of automatic control systems. Emphasizes a sound foundation in the classical control techniques upon which more advanced subjects can build. Use of digital computer program in the solution of illustrative homework problems. Compensation techniques and design examples to meet performance specifications. Recommended for the second term of the junior year or later.
W. R. Markey

16.312 Principles of Optimal Control (A)

Prereq.: 16.341J, 16.37
G (2)
3-0-9

Studies the principles of deterministic optimal control. Pontryagin's maximum principle. Applications of the theory, including optimal feedback control, time-optimal control, and others. Dynamic programming, numerical techniques. Optimal estimation and control in the presence of uncertainties.
W. E. Vander Velde

16.321 Fault-Tolerant Control Systems (A)

Prereq.: 16.37
G (2) **Next offered 1989-90**
3-0-9

Design and analysis of control systems that can sustain component failures and continue to function. Presents an overview of the subject area. Statistical failure models. Methods for masking component failures. Methods for detecting and isolating component failures. Evaluates performance of redundant control systems. Alternate years.
S. R. Hall

16.33 Computer Control of Dynamic Systems (A)

Prereq.: 16.30
G (1)
3-0-9

Elements of linear discrete-time system theory: state description, stability, z-transform analysis, controllability, observability, canonical forms. Analyzes linear discrete-time control systems: stability, root locus, frequency response. Synthesis of state feedback computer control systems: stability improvement, deadbeat controllers, minimum quadratic cost optimal regulators. Control of systems with incomplete state measurements: observers, properties of observer-regulator computer controllers.
S. R. Hall

16.34 Advanced Control of Flight Vehicles (A)

Prereq.: 16.30
G (2)
3-0-9

Application of design techniques and principles to advanced control systems for air and space vehicles. Review of nondimensional equations of motion. Classical and modern control techniques applied to flight vehicle stabilization. Time and frequency domain analysis of control system performance. Models for pilot-in-the-loop control. Prediction and validation of vehicle handling qualities. Introduction to digital control techniques. Control system design to meet mission requirements, including robustness criteria. Adaptive control and display design.
S. R. Hall

16.341J Multivariable Control Systems I (A)

(Same subject as 2.154J, 6.233J, 10.28J, 13.481J)
Prereq.: 2.14 or 6.302 or 10.35 or 16.30
G (1)
4-0-8

See description under subject 6.233J.
M. Athans, J. K. Hedrick, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

16.342J Multivariable Control Systems II (A)

(Same subject as 2.155J, 6.234J, 10.29J, 13.482J)
Prereq.: 16.341J
G (2)
4-0-8

See description under subject 6.234J.
M. Athans, J. K. Hedrick, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

16.351J Quantitative Physiology: Sensory and Motor Systems

(Same subject as 2.793J, 6.023J, HST 543J)
Prereq.: 2.02 or 6.003 or 16.30
U (2)
3-2-7

See description under subject 6.023J.
L. R. Young, L. S. Frishkopf, R. W. Mann

16.352J Sensory-Neural Systems (A)

(Same subject as 6.532J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

See description under subject 6.532J.
L. R. Young, L. S. Frishkopf

16.355J Models of Man-Machine Systems (A)

(Same subject as 2.181J)
Prereq.: 18.03
G (1)
3-1-8

See description under subject 2.181J.
T. B. Sheridan

16.356J Biomedical Signal Processing (A)

(Same subject as 6.555J, HST 582J)
Prereq.: 6.003
G (2)
3-6-3

See description under subject HST 582J.
B. Delgutte, W. M. Siebert, P. Albrecht

16.359 Bioengineering Journal Article Seminar

Prereq.: —
G (1, 2)
0-2-0

Each term, the class selects a new set of professional journal articles on bioengineering topics of current research interest. Some papers are chosen because of particular content, others are selected because they illustrate important points of methodology. Each week, one student leads the discussion, evaluating the strengths, weaknesses, and importance of each paper. Subject may be repeated for credit a maximum of four terms. Letter grade given in the last term applies to all accumulated units of 16.359.
C. M. Oman

16.36 Flight Simulation (A)

Prereq.: 18.03, 16.30 or 6.003 or 2.14
G (1) **Not to be offered 1989-90**
3-6-3

Simulation of aircraft for research and pilot training. Conversion of aircraft equations of motion and data package into a digital computer model. Simplified transfer functions. Principles of vision relevant to out-the-window displays. Implementation of CRT, model board, and point light source displays. Cockpit motion requirements, motion washout, artificial control, and feel and high-g cuing devices. Students participate in actual simulator problems in the lab. Assumes familiarity with FORTRAN programming.
L. R. Young, W. M. Hollister

16.37 Statistical Problems in Automatic Control (A)

Prereq.: 16.30
G (1)
3-0-9

Statistical problems of importance to control-system engineers. Reviews probability theory, with application to such problems as system reliability and multidimensional random errors. Measurement of the statistics of random variables and processes. Extensive treatment of random processes in linear systems, using both transfer function and state-space descriptions. Design of optimum filters according to Wiener and Kalman.
W. E. Vander Velde

16.371 Estimation and Control of Stochastic Processes (A)

Prereq.: 16.37
G (2)
3-0-9

Brief review of stochastic process fundamentals; some stochastic realization theory. Bayesian estimation. Linear filtering and smoothing; linear prediction. Kalman filter (discrete and continuous time). Implementation issues; filter stability, steady-state properties, sensitivity to modeling errors, sensors. Numerical robustness; square root formulations. Extended Kalman filter, Gaussian second-order filter; convergence analysis. Adaptive filters.
L. Valavani

16.375 Adaptive Control (A)

Prereq.: 16.342J
G (1)
3-0-9

Studies nonlinear dynamic system concepts, with emphasis on stability: Lyapunov and hyperstability theories. Introduces sensitivity and gradient methods as precursors to adaptive control. Adaptive observers (minimal and nonminimal). Model Reference Adaptive Control (MRAC) and Self-Tuning Regulators (STR); deadbeat controllers. Direct and indirect methods. Stability and parameter convergence of existing algorithms. Robustness properties of adaptive systems and design implications. State-of-the-art results and current open problems.
L. Valavani

16.381 Lasers and Optics for Applications I (A)

Prereq.: 8.03
G (1)
3-0-9

An introduction to fundamentals of modern optics and lasers, intended for those interested in laser applications. Presents a simplified account of lasers and their coherence properties: optics of laser beams and the propagation of light in vacuum, dielectrics, and fibers. Basics of laser "gyroscopes," and the use of lasers and fiberoptics in displacement, velocity, temperature, pressure, and acoustic sensing.
S. Ezekiel

16.382 Lasers and Optics for Applications II (A)

Prereq.: 16.381 or 6.631 or 8.243
G (2)
3-0-9

Continuation of 16.381, emphasizing a more advanced treatment of lasers. Interaction of radiation with atoms, stimulated and spontaneous emission, and line-broadening mechanisms. Steady-state and transient behavior of lasers. Survey of gas, liquid, solid, and semiconductor lasers. Nonlinear optics. Modulation and deflection of light. Harmonic generation and mixing. Laser spectroscopic techniques, with emphasis on specie identification and resolution.
S. Ezekiel

16.39 Algorithms for Function Minimization and Optimal Control (A)

Prereq.: 18.076 or 18.085
G (2) **Not to be offered 1989-90**
3-0-9

Develops techniques for seeking the minima of functions and optimal control histories for dynamic systems. Presentation based on fundamentals of function optimization and optimal control theory. Introduces variational calculus, the maximum principle, and dynamic programming. Considers unconstrained and constrained problems. Compares the complexity and performance of different optimum-seeking algorithms.
W. E. Vander Velde

16.40 Principles of Flight Guidance

Prereq.: 16.30 or 6.302
U (2)
3-1-8

Introduces navigation and guidance of flight vehicles. Basic concepts of position and velocity determination, using celestial, inertial, and radio techniques. Guidance strategy for aircraft and spacecraft applications. Steering laws for rocket-powered flight, atmospheric reentry, and air traffic control. Familiarity with rigid body dynamics and elementary automatic control theory desirable.
R. J. Hansman

16.41 Inertial Engineering I (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

First half treats motion with respect to inertial space, gyroscopic instrument theory, gimbal systems, Schuler tuning, and the design of the three principal inertial navigation systems. Second half introduces practical aspects of inertial instruments and systems. Analyzes and evaluates single and two degree of freedom instruments and their errors. Includes laser, electrostatic and dry-tuned gyros, and models of state-of-the-art hardware. Students obtain a thorough understanding of inertial space concepts and hardware.
W. R. Markey

16.46 Astrodynamics I (A)

Prereq.: 18.03
G (1)
3-1-8

Fundamentals of astrodynamics; the two-body orbital initial-value and boundary-value problems with applications to space vehicle navigation and guidance for planetary exploration. Topics: orbital mechanics, Kepler's problem, universal orbital variables, Lambert's problem, recursive algorithms, Lagrange's expansion theorem, hypergeometric functions, Bessel functions, continued fractions and quaternions. Selected applications from the Apollo and Space Shuttle programs.
R. H. Battin

16.47 Astrodynamics II (A)

Prereq.: 16.46
G (2)
3-1-8

Fundamentals of space vehicle guidance with applications for both powered flight and midcourse maneuvers; fundamentals of space vehicle navigation emphasizing self-contained methods and statistical analysis. Topics: precision orbit determination methods, variation of parameters, linearized and explicit techniques for targeting, state-space methods, maximum-likelihood estimates, numerical integration, elliptic integrals, Legendre functions, hodograph analysis and application of optimization principles.
R. H. Battin

16.491 Selected Topics in Celestial Mechanics (A)

Prereq.: 8.03, 18.076
G (1)
3-0-9

Reviews the two-body problem. Variational principles in dynamics, leading to Lagrange's equations, the canonical equations, and canonical transformations. The Hamilton-Jacobi equation, with solution for the Kepler problem, leading to canonical perturbation methods, Delaunay variables, and Lagrange's variational equations. Gravitational potential of a planet and rotational motions of the earth and moon. First-order theory of the orbits of artificial satellites, including the effects of atmospheric drag.
J. P. Vinti

16.492 Selected Topics in Celestial Mechanics (A)

Prereq.: 16.491
G (2)
3-0-9

Brouwer-Von Zeipel method and method of Lie transforms, with applications to the orbits of artificial satellites and lunar orbiters. Separable problems, including the spheroidal method, Staeckel systems, and effects of general relativity on orbit of a planet or satellite. Selected topics from the three-body problem, planetary and lunar theory, resonant motions, periodic orbits, and stability theory.
J. P. Vinti

16.53 Rocket Propulsion

Prereq.: 16.004
U (1, 2)
3-1-8

Velocity requirements for orbital and interplanetary flight. Available velocity increments and staging. Treats rocket systems involving liquid, solid, and hybrid propellants, with reference to nozzle flows, thermochemistry, real gas effects, losses and heat transfer, structural constraints, propellant feed, and combustion. Simple vehicle optimization. Laboratory demonstrations.
D. E. Hastings, A. H. Epstein

16.531 Space Propulsion and Power Generation (A)

Prereq.: 16.53, 8.03
G (2)
3-0-9

Reviews rocket propulsion fundamentals. Discusses advanced thruster concepts from air-breathing boosters to electric propulsion. Liquid rocket pressurization schemes. Physics and engineering of small thrusters for station-keeping and attitude control. Methods and concepts for electric power generation in space; photovoltaic, solar, thermal, and nuclear systems; and various conversion schemes. Power transmission and reception.
Staff

16.54 Aircraft Engines and Gas Turbines

Prereq.: 16.004
U (1)
3-1-8

Performance and characteristics of aircraft engines and industrial gas turbines, as determined by thermodynamic and fluid mechanic behavior of components: inlets, compressors, combustors, turbines, nozzles. Discusses various engine types, including turbojet, turbofan, and turboprop. Limitations imposed by material properties and stresses. Emphasizes future design trends, including reduction noise, pollutant formation, fuel consumption, and weight.
A. H. Epstein

16.541 Aircraft Turbine Engines (A)

Prereq.: 16.54
G (1)
3-0-9

Fluid mechanics, thermodynamics, and solid mechanics of aircraft turbine engines. Steady two-dimensional and three-dimensional flow theories of compressors and turbines. Unsteady flow and noise production in turbomachinery and in complete engines. Operational limitations and instabilities. Stress and associated temperature limits and influence of blade cooling techniques on turbines.
E. M. Greitzer

16.543 Internal Flows in Turbomachines (A)

Prereq.: 16.035 or 2.25
G (2) **Not to be offered 1989-90**
3-0-9

General features of internal flows with application to compressors and turbines. Fundamental concepts of rotational flows, inherent unsteadiness of turbomachines, boundary layers, wakes, and losses in turbomachines. Axisymmetric swirling flows, blade element theory, streamline curvature computations. Effects of viscosity and compressibility in internal flows. Secondary flows. Flow instabilities in turbomachines. Recent developments and experimental information. Alternate years.
E. M. Greitzer

16.544 Hypersonic Airbreathing Propulsion (New)

Prereq.: 16.02 or equivalent, 16.54 or 16.53; 16.051 or 2.271 recommended, but not required
G (1)
3-0-9

A first-year graduate course on fundamentals of high speed airbreathing engines. The essential fluid mechanics is first reviewed, and the course proceeds to the simple cycle and one-dimensional analysis of Ramjets with subsonic or supersonic combustors. Chemical kinetics, jet mixing, and effects of heat addition to a high speed flow are then considered. Other topics include viscous effects, boundary layer separation, and cooling effects and requirements. Finally, integration with the airframe, trajectory constraint, and mission analysis are also included.
M. Martinez-Sanchez

16.55 Ionized Gases (A)

Prereq.: 8.211
G (1) **Not to be offered 1989-90**
3-0-9

Properties and behavior of low-temperature plasmas for magnetohydrodynamics, thermionic energy conversion, plasma propulsion, gas lasers. Equilibrium of ionized gases: energy states, statistical mechanics, and equilibrium. Kinetic theory: motion of charged particles, distribution function, collisions, characteristic lengths and times, cross-sections, transport properties. Gas surface interactions: thermionic emission, sheaths, probe theory. Radiation in plasmas, diagnostics. Alternate years.
M. Martinez-Sanchez

16.551 Plasmadynamics and Magnetohydrodynamics

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Motion of conducting fluids in electric and magnetic fields. Electrodynamics: discharges and arcs, current transfer to immersed electrodes, effect of the Lorentz Force on flow. Magnetohydrodynamics: power generation and propulsion, simple inviscid and compressible flows, electric conductivity, Hall effect, ion slip, nonequilibrium electronic heating, viscous effects, nonuniformities, time-dependent MHD performance. Plasma generators, thrusters, circuit breakers, and MHD generators.
Staff

16.56 Noise Control Engineering (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Reviews physical principles of noise generation, transmission, and absorption, and the effect of noise on humans. Noise rules and criteria. Specific topics: aerodynamic noise, compressor, fans, and propellers, acoustically induced instabilities in valves, heat exchangers. Mufflers and duct-liner technology.
K. U. Ingard

16.60 Advanced Special Project (A)

Prereq.: —
G (1, 2, S)
Arr.

Study, original investigation, or lab project work of graduate level by qualified students. Topics selected in consultation with instructor.
H. Y. Wachman

16.601 Advanced Special Subject (A)

Prereq.: —
G (1, 2)
Arr.

16.602 Advanced Special Subject

Prereq.: —
G (1, 2)
3-0-6

Organized lecture or laboratory subject, consisting of graduate-level material not available in regularly scheduled subjects.
H. Y. Wachman

16.605 Special Projects

Prereq.: —
U (1, 2, S)
Arr.

Study or laboratory project work of undergraduate level by qualified students. Topics selected in consultation with the instructor.
W. R. Markey

16.606 Selected Topics in Aeronautics and Astronautics

Prereq.: —
U (1, 2)
Arr.

Study at the undergraduate level by qualified students. Topics selected in consultation with the instructor.
W. R. Markey

16.608J Biomedical Instrumentation Electronics

(Same subject as 2.781J, HST 570J)
Prereq.: Permission of Instructor
G (S)
6-6-6

See description under subject HST 570J.
D. Rowell, S. K. Burns

16.61 Microcomputer Laboratory

Prereq.: 6.071 or 6.002; 2.10
U (1, 2)
2-8-2

Explores the operation of microcomputers and methods of interfacing digital and analog devices to microcomputers. Machine and assembly language programming. Use of software development system. Parallel and serial digital interfaces. Digital-to-analog and analog-to-digital conversion. Timing and interrupts. Arithmetic limitations. Software versus hardware trade-offs. Control of real-time events and physical systems. Final project: automatic control of electromechanical system. Limited enrollment.
D. L. Akin

16.621 Experimental Projects I

Prereq.: 16.004
U (1, 2)
1-1-1

Introduces laboratory experimental techniques. Principles of reliable measurements. Laboratory safety. Instruction in effective report writing and oral presentation. Selection and detailed planning of an individual research project, including design of components or equipment. Preparation of a detailed proposal for the selected project carried through to completion under 16.622.
R. J. Hansman

16.622 Experimental Projects II

Prereq.: 16.621
U (1, 2) LAB
1-7-4

Helps student gain practical insight and improved understanding of engineering experimentation through design and execution of "project" experiments. Building upon work in 16.621, student constructs and tests equipment, makes systematic experimental measurements of phenomena, analyzes data, compares theoretical predictions with results. Written final report on entire project and formal oral presentation. Provides valuable link between theory and practice.
R. J. Hansman

16.64 Flight Measurement Laboratory

Prereq.: 16.002
U (2)
2-2-2

Opportunity to see aeronautical theory applied in real-world environment of flight. Students assist in design and execution of simple engineering flight experiments in light aircraft. Typical investigations include determination of stability derivatives, verification of performance specifications, and measurement of navigation system characteristics. Limited to students in Aeronautics and Astronautics.
R. J. Hansman

16.65 Measurement, Instrumentation, and Computers (A)

Prereq.: 16.02, 16.20, 6.071
G (2) **Next offered 1989-90**
3-0-9

Foundation for experimentation in aerodynamics and structural mechanics, including sensor selection, analogue signal processing, and computer data acquisition. Emphasizes physical system constraints and the practical aspects of experimentation. Alternate years.
A. H. Epstein

16.671J Invention

(Same subject as 2.941J)
Prereq.: —
G (1)
3-0-6

See description under subject 2.941J.
W. R. Markey, W. C. Flowers, A. D. Carmichael

16.672 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
W. C. Flowers

16.673 Inventions and Patents

Prereq.: 14.02
U (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. H. Rines

16.701 Principles of Systematic Policy Analysis

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-6

Introduces the systematic analysis of policy choices, emphasizing approaches, concepts, and techniques employed. Main focus on techniques for comparing major project or program alternatives. Studies time-streams of benefits and costs. Pertinent operations research techniques, including linear and integer programming, project scheduling, and game theory. Introduces decision analysis and utility theory.
A. R. Odoni

16.704J Seminar in Air Transportation Analysis and Planning

(Same subject as 1.233J)
Prereq.: —
G (1)
1-0-5

A review of current issues facing the airline industry in operational, economic, financial, regulatory, and institutional areas. Seminars are presented on alternative weeks by leading speakers from airlines, aircraft manufacturers, major airports, regulatory agencies, and national and international aviation organizations. Preparatory lectures precede each seminar. Opportunity for students to conduct studies on particular topics, with readings guided by staff. Term paper required.
C. O. Cary, A. R. Odoni

16.72 Air Traffic Control (A)

Prereq.: 6.071 or 16.40
G (1)
3-0-6

Introduces the various aspects of present and future Air Traffic Control systems. Descriptions of the present system: systems-analysis approach to problems of capacity and safety; surveillance, including NAS and ARTS; navigation subsystem technology; aircraft guidance and control; communications; collision avoidance systems; sequencing and spacing in terminal areas; future directions and development; critical discussion of past proposals and of probable future problem areas. Requires term paper.
R. W. Simpson

16.74 Air Transportation Economics (A)

Prereq.: —
G (1)
3-0-6

Introduces fundamental concepts for the economic analysis of airline systems. Contrasts basic models of the operation of air transport markets with neoclassical microeconomic models. Defines market systems for air transport service, and develops a theory for pricing, demand, costs, and supply for regulated and unregulated, domestic and international markets. Presents market models for equilibria in isolated markets and over a network of markets.
R. W. Simpson

16.752J International Air Transportation

(Same subject as 17.334J)
Prereq.: —
G (1)
3-0-6

Emphasizes political aspects of international air transport. Topics: international civil aircraft industry; types of airline ownership; characteristics of air transport in North and South America, Europe, Middle East, Africa, Asia, USSR; world route patterns; bilateral negotiations; international air transport organizations; air transport in developing nations; unlawful interference with aircraft; international air-cargo industry. Term paper.
B. R. Gidwitz

16.76J Logistical and Transportation Planning Methods (A)

(Same subject as 1.203J, 6.281J, 11.526J, 13.665J, 15.078J)
Prereq.: 6.431, 15.075
G (1)
3-0-9

See description under subject 1.203J.
A. R. Odoni, A. I. Barnett, R. C. Larson, H. N. Psaraftis

16.77 Flight Transportation Operations Analysis (A)

Prereq.: 15.081
G (2)
3-0-6

Studies application of linear programming and network flow theory to operational problems in flight transportation systems. Reviews graph theory. Network flow theory. Integer programming and branch and bound methods. Dynamic programming. Reviews implementation of computerized mathematical programming systems. Applies the theory to scheduling, aircraft and crew routing, timetable optimization, passenger traffic flow, flight planning, etc. Students use computer to solve large-scale problems and for term project.
R. W. Simpson

16.781J Planning and Design of Airport Systems (A)

(Same subject as 1.231J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

See description under subject 1.231J.
A. R. Odoni, R. de Neufville

16.784 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. de Neufville, J. P. Clark

16.792 Introduction to Technology and Law

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. D. Nyhart

16.793 Probabilistic Models in Engineering (Revised Content)

Prereq.: 1.03 or 6.041 or 18.05
U (2)
3-2-7

New School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. R. Odoni, R. C. Larson, H. N. Psaraftis

16.794 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

16.80 Industrial Practice

Prereq.: —
U (1, 2) [P/F]
0-8-0

Seven months of engineering practice, carried out by the cooperative students at the plants of organizations participating in the cooperative program.
E. F. Crawley

16.801 Engineering Internship

Prereq.: —
U (S) [P/F]
0-6-0

A summer of work experience as part of the Engineering Internship Program. Students register for this subject twice, receiving the grade "J" for the first registration. Two work assignments must be completed in order for credit to be awarded. Limited to students registered in Course XVI-C.
W. E. Vander Velde

16.802 Advanced Engineering Internship

Prereq.: 16.801
G (1, 2, S) [P/F]
0-6-0

A consecutive seven-month period of work experience as part of the Engineering Internship Program. Students register for this subject in two terms, receiving the grade "J" for the first registration. Limited to students registered in Course XVI-C who have been admitted to the Graduate School.
W. E. Vander Velde

16.81 Space Flight Dynamics

Prereq.: 16.004, 18.03
U (1)
3-0-9

Topics: launch trajectory analysis, orbit insertion navigation requirements, orbital mechanics and spacecraft dynamics, the space environment (gravity gradients, atmospheric drag, radiation environment), rendezvous and docking approaches, thermal equilibrium, reentry trajectory analysis, convective and radiative heating, thermal protection system analysis, hypersonic maneuvering, and landing dynamics of low L/D vehicles.
W. M. Hollister

16.821 Management Topics in Engineering

Prereq.: —
G (2)
2-0-4

Directed toward the student whose objective is a career in engineering leading to management. Provides opportunities to examine topics relating to the conduct of engineering activities within a total management environment. Interfaces between engineering and other company functions, such as marketing, finance, manufacturing, quality, explored with emphasis on the management process. Special attention given to the role of technical staff in the acquisition of new business and long-range planning. Seminar format based on current industrial practice.
J. Yamron

16.84 Flight Vehicle Engineering

Prereq.: 16.02 or 16.20
U (1)
2-3-7

Design of an atmospheric flight vehicle to satisfy stated performance, stability, and control requirements. Emphasizes individual initiative, application of fundamental principles, and the compromises inherent in the engineering design process. Enrollment restricted to seniors in Course XVI or by permission of instructor.
N. D. Ham

16.85 Space Systems Engineering

Prereq.: 16.20
U (2)
4-0-8

Reviews fundamental principles used in engineering development of space systems. Design of a complete system, including trajectory analysis, entry dynamics, propulsion systems, structural design, thermal control, environmental control, support systems, weight and cost estimates. Students participate in teams, each responsible for one of several subsystems, providing experience in project organization and interaction between disciplines. Enrollment restricted to seniors in Course XVI or by permission of Instructor.
D. L. Akin, D. E. Hastings, J. W. Mar

16.851 Satellite Engineering (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Fundamentals of satellite engineering design. Studies orbital environment. Analyzes problems of station keeping, attitude control, communications, power generation, structural design, thermal balance, and subsystem integration. Considers trade-offs among weight, efficiency, cost, and reliability. Discusses choice of design parameters, such as size, weight, power levels, temperature limits, frequency, bandwidth. Examples taken from current satellite systems.
W. M. Hollister

16.852 Spacecraft and Aircraft Instrumentation (A)

Prereq.: 6.071, 8.03
G (1) **Not to be offered 1989-90**
3-0-9

Covers fundamental instrumentation principles in the context of systems designed for space or atmospheric flight. Systems discussed are incoherent and doppler radars; space communications; spacecraft attitude determination by stellar, solar, and horizon sensing; remote sensing by radiometry, spectrometry, and interferometry; air data systems; and radio navigation. Also, review of basic electromagnetic theory and antenna design. Discussion of design considerations for flight. Alternate years.
R. J. Hansman

16.87 VTOL Aircraft (A)

Prereq.: 16.02
G (1) **Next offered 1989-90**
3-0-6

An analytical discussion of the fundamental performance, stability, and control characteristics of vertical take-off and landing aircraft, including helicopters and ducted fan, rotor-propeller, jet vectored-lift, and jet vertical-lift aircraft. Alternate years.
N. D. Ham

16.88 Aerodynamics, Structural Dynamics, Aeroelasticity of Wind Turbines and Rotorcraft (A)

Prereq.: 16.02
G (1) **Not to be offered 1989-90**
3-0-6

An analytical discussion of fundamental aerodynamic, structural dynamic, and aeroelastic characteristics common to wind turbines and rotorcraft. Includes the horizontal axis and vertical axis types of wind turbine, and the helicopter and tilting rotor-propeller types of rotorcraft. Alternate years.
N. D. Ham

16.91 Structural Dynamics (A)

Prereq.: 16.20
G (1)
3-0-9

Vibrations of simple and complex structures: bars, strings, rods, beams, plates; emphasizes physical concepts. Analyzes continuous and multimass systems. Formulation and application of diverse methods; finite element, Galerkin, integral equation, and numerical collocation. Variational principles in dynamics: Hamilton's Principle and Lagrange's equations. Transient response solution by modal superposition and direct numerical integration techniques. Self-excited vibrations, dynamic stability. Wave propagation concepts. See 2.032 and consult advisor.
A. H. von Flotow

16.92 Advanced Aeroelasticity (A)

Prereq.: 16.004, 16.91
G (2) **Next offered 1989-90**
3-0-9

Presents field of aeroelasticity from unified viewpoint, applicable to flight structures as well as buildings, suspension bridges, and other structures. Static aeroelastic and flutter instabilities of simple and complex structures. Similarity lows and wind-tunnel modeling. Responses to gusts and random excitation. Derivation of unsteady airloads. Simple nonlinear aeroelastic behavior. Alternate years.
J. Dugundji

16.93 Dynamics of Space Structures (A)

Prereq.: 16.91, 16.341J
G (2) **Not to be offered 1989-90**
3-0-9

Presents control-structural dynamic interaction from a unified viewpoint, applicable to flexible space structures, precision structures, and aero-servo-elastic lifting surfaces. Damped structures, modeling of dissipative and nonlinear effects. Mode shape-wave duality in structures. Approximate and continuum modeling. Formulations of controllers for reduced-order models. Control-structure interaction and spillover. System identification. Deployment and assembly dynamics. Alternate years.
E. F. Crawley

16.94 Advanced Structural Dynamics (A)

Prereq.: 16.91
G (1) **Next offered 1989-90**
3-0-9

Reviews transient response of linear systems. Emphasizes nonlinear vibrations and transient response of structures; elastic and inelastic material behavior and large deflections. Modal and direct numerical timewise integration techniques. Transient strain and displacement responses; permanent deformation. Impact and propagation of both elastic and inelastic stress waves in solids. Wave propagation and scattering in structural networks and in periodic structures. Mechanical filtering. Forced and parametric excitation. Alternate years.
A. H. von Flotow

16.991 Aeronautics and Astronautics Seminars

Prereq.: —
U (1, 2) [P/F]
2-0-0

Speakers from campus and industry discuss current activities and advances in aeronautics and astronautics. Restricted to Course XVI students.
W. R. Markey

16.992 Seminar

Prereq.: —
G (1, 2) [P/F]
2-0-0

Discussion of current interest topics by staff and guest speakers. Restricted to Course XVI students.
W. R. Markey

16.993 Management in Engineering

Prereq.: —
U (1)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult, H. S. Marcus

16.994 Nuclear War: Threat and Avoidance

Prereq.: —
U (2) HASS
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

16.995 Nuclear Weapons and Arms Control: Technology and Folicy Issues

Prereq.: —
G (1)
4-0-8

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
G. W. Rathjens, J. P. Ruina

16.ThG Graduate Thesis (A)

Prereq.: —
G (1, 2, S)
Arr.

Program of graduate research, leading to an S.M., E.A.A., Ph.D., or Sc.D. thesis; to be arranged by the student with an appropriate MIT faculty member, who is then thesis supervisor.
H. Y. Wachman

Course 17 Political Science

Political Philosophy/Social Theory

17.104J Philosophies of Social Science (A)

(Same subject as 24.625J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Addresses philosophical issues arising in contemporary social scientific research practice. Issues of explanation and understanding, the justification of theories and arguments, objectivity and commitment in political research.
U. Mehta

17.105J Political Philosophy

(Same subject as 24.233J)
Prereq.: One Philosophy Distribution subject
U (1)
3-0-9

17.106J Political Philosophy (A)

(Same subject as 24.611J)
Prereq.: One Modern Political Philosophy subject
G (1)
3-0-9

A comparison of different conceptions of social justice through a study of both classical and contemporary political philosophy. Topics include contractualist and utilitarian justifications of the state; the role of rights in political argument; communitarian criticisms of liberalism; the alleged tensions between liberty and equality; and problems of fair distribution of resources. Meets with 17.105J.
J. Cohen

17.107 Introduction to Political Theory: Individual and Community

Prereq.: —
U (1) HUM-D
3-0-6

Basic introduction to the study of politics, focusing on selected works in classical, medieval, and early modern political thought. The claims to freedom of the individual as they encounter demands of the community for order, justice, and obedience. Extent to which political society is justified in shaping the lives and consciousness of its members. Foundations of political authority. Readings include Plato, Aristotle, St. Augustine, Machiavelli, and Hobbes.
U. Mehta

17.109J Philosophy of Law

(Same subject as 24.235J)
Prereq.: One Philosophy subject
U (2) **Next offered 1989-90**
3-0-9

See description under subject 24.235J.
J. Cohen

17.110 New Currents in Social Theory (A)

Prereq.: —
G (1) **Next offered 1989-90**
3-0-9

The course begins by discussing some classical debates in social theory; e.g., the sources on instability in slave systems and the notion of a determinate logic of social progress. The second part reconsiders these debates in light of contemporary social scientific and historical research. The third part uses the results of the first two segments to address several contemporary debates in social theory: e.g., the role of moral sentiments in explaining political action and the plausibility of evolutionary explanations of social change.
C. F. Sabel

17.111 Modern Social Theory (New)

Prereq.: —
U (1)
3-0-9

17.112 Modern Social Theory (A) (New)

Prereq.: —
G (1)
3-0-9

This seminar studies selected writings of Tocqueville, Marx, Weber, and Durkheim. It focuses on three broad issues: (1) In trying to understand social/political change, what are the significant social nexuses for these theorists; (2) the explanatory accounts that these theorists give of "major" historical changes, (e.g. feudalism to capitalism, aristocracy to democracy, "traditional" to "rational" societies); (3) the theoretical and explanatory significance of non-Western societies and "marginal" groups in the work of these theorists. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.111.
U. Mehta

17.113J Classics in Political Philosophy

(Same subject as 24.09J)
Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

See description under subject 24.09J.
U. Mehta

17.115J Justice (New)

(Same subject as 24.04J)
Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

An examination of alternative theories of justice — utilitarianism, rights theories, social contract theory, and communitarianism — and the implications of those theories for problems of liberty, equality, and community. Readings are drawn principally from the work of contemporary political philosophers, including Rawls, Nozick, Dworkin, Walzer, MacIntyre, and Buchanan.
J. Cohen, D. Brink

Political Economy

17.154J Politics of Industrialization (A)

(Same subject as STS 504J)
Prereq: Permission of Instructor
G (2)
3-0-9

Focuses on the way the pace and direction of economic development depend upon the outcomes of historical struggles for justice and the control of resources: politics in the broadest sense. Shows how both the industrial structure of mass-production capitalism and the definition of the interests of groups that occupy places in that structure cannot be understood without reference to these struggles.
C. F. Sabel

17.156J Political Economy I: Theories of the State and the Economy (A)

(Same subject as 14.781J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Critical analysis of liberal, neoclassical, and Marxist perspectives on modern society. Alternative theories of economic growth, historical change, the state, classes, and ideology.
S. Berger, M. J. Piore

17.158 Political Economy of West Europe (A)

Prereq.: 17.534 or 17.156J
G (2) **Next offered 1989-90**
3-0-6

Examines role of European states in postwar period of rapid economic growth and current crisis. Includes analysis of different state traditions ("etatist," liberal, authoritarian); government's role in decline of some economies and rise of others; why and where Keynesianism, indicative planning, and state enterprises were introduced; alternative conceptions of contemporary economic problems (new international division of labor? too few producers? oil shock?); and of policies to deal with them (industrial policy? monetarism? protectionism?).
S. Berger

17.160 Political Sociology (A) (New)

Prereq.: Permission of Instructor
G (1)
3-0-9

Provides a general introduction to the field of Political Sociology. Covers works by the classical theorists (Tocqueville and Weber) as well as the emergence of the discipline in the postwar period (Bendix, Lipset, Dahl, Truman). While subject reviews the main paradigms treating the relations between politics and society, the focus is on institutionalist approaches. Central issues include: the problem of democracy, the conflict between bureaucracy and democracy, relations between elite and mass, the representation of interests, and the theory of collective identities.
E. M. Immergut

17.162 States in History and Theory (A) (New)

Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

Aims to familiarize students with the archetypal forms of the modern state and with debates regarding its true nature. Also intended to allow American students of social science to understand foreign students' often unspoken presuppositions about politics, and vice versa. Explores the link between the study of policy as defined in American social science and the study of political economy as defined elsewhere. Examines politically pressing problems regarding the reorganization of the welfare state in the OECD countries.
C. F. Sabel

17.164 Labor and Politics (A)

Prereq.: —
G (2)
3-0-9

The evolution of the American labor movement from its colonial beginning to the present. The artisan tradition; populism and the cooperative commonwealth; craft unionism; socialism; the welfare capitalism of the 1920s; the sources of protest in the 1930s and the limited transformation of the American industrial relations system; industrial pluralism and postwar prosperity; the breakdown of the postwar system and efforts, rooted in the unrealized opportunities of labor's traditions, to reestablish the institutional security of the labor movement.
C. F. Sabel

17.166J Problems of Advanced Industrial Societies (A)

(Same subject as STS 506J)
Prereq.: 17.156J
G (2) **Next offered 1989-90**
3-0-9

Analyzes selected current political economy issues. Includes inflation, industrial relations systems, the "crisis of ungovernability," public assistance and family policy, and "reindustrialization." Open to qualified undergraduates by permission of instructor.
S. Berger, M. J. Piore

17.167 Political Economy of Asia

Prereq.: —
U (1)
3-0-9

17.168 Political Economy of Asia (A)

Prereq.: —
G (1)
3-0-9

Comparative analyses of economic and political developments of India, China, Japan, and Korea-Taiwan-Singapore. Focuses on the politics of economic planning, relationships between policy and performance, political and social consequences of different developmental approaches, and Asian economics in global perspective. Meets with 17.167.
L. W. Pye

17.170 The Political Economy of International Migration (A)

Prereq.: —
G (2)
3-0-9

Explores the political causes and consequences of population movements across international boundaries and within states. Detailed examination of the following: political effects of urban migration, political behavior of political refugees, consequences of internal population movements in multiethnic societies, economic and political impact of migrants on the receiving country, effects of migration on the country of origin. Draws case materials from contemporary Asia, Africa, and Latin America.
M. Weiner

See also 17.422.

American Politics/Public Policy

Public Policy

17.201J Politics and Public Policy

(Same subject as 11.007J)
Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Introduction to political aspects of public policy. Considers philosophical rationales for government action and the evolution of public policy in America; the policy-making process; basic strategies of public policy, including markets, government regulation, mass persuasion; and ways of analyzing the impacts of public policies — social indicators, cost/benefit analysis, evaluation of distributive equity, and unintended consequences.
E. M. Immergut, M. Lipsky, G. T. Marx

17.202 Theories of Public Policy (A)

Prereq.: —
G (2)
3-0-9

Analyzes the effects of political structures on public policies from conceptualization to enactment and implementation. Topics include normative theories of state intervention; interest-group/government relations; the effects of scale and arenas; bureaucracy and complex organizations; comparative public policy. Students apply theoretical issues to a policy topic of their choice.
E. M. Immergut

17.203 Political Science Laboratory

Prereq.: —
U (1) LAB
3-5-4

Introduces students to the conduct of political research using quantitative methodologies. The methods are examined in the context of specific political research activities like public opinion surveys, voting behavior, Congressional behavior, comparisons of political processes in different countries, and the evaluation of public policies. Students participate in joint class projects and conduct individual projects. May *not* count toward HASS Requirement.
C. Stewart

17.206 The Welfare State in Comparative, Historical Perspective (A)

Prereq.: —
G (1)
3-0-9

Introduces recent debates on the welfare state, both as they concern specific social policies and as they treat the welfare state *qua* state. Ranging from convergence theory to the new institutionalism, these approaches are assessed in the light of a series of case studies that include workmen's compensation, full employment, and health policy. Issues addressed: How can one define "the welfare state?" What are the dimensions of comparison across nations (mainly Western Europe and North America)? What makes the US case exceptional? As a political entity, how is the welfare state unique?
E. M. Immergut

17.213 Regulation

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

17.214 Regulation (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Analyzes theoretical issues that cut across many substantive areas of regulation, including health and safety, environment, energy, and transportation. Topics: deciding when to regulate, explaining the behavior of regulatory agencies, evaluating alternative regulatory instruments, evaluating proposals for regulatory reform and deregulation. Literature drawn from law, economics, and political science. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.213. Consult Department Headquarters.

17.220J The Policy-Making Process (A)

(Same subject as TPP 22J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Analyzes the political process by which issues arise, and the public policies that are formulated, contested, determined, implemented, and evaluated. Treats the role of mass activity (including protest politics), professional expertise, elites, the media, and public officials in the stages of the policy process. Weighs the relationship between popular and programmatic responsiveness and distributive consequences of policy.
M. Lipsky

17.222 The Organization of Public Policy (A)

(17.274)
Prereq.: —
G (2)
3-0-9

Analyzes the political and policy implications of delivering policy through public, nonprofit, and private organizations. Examines the role of public services in the American political economy. Emphasizes comparisons across policy areas, such as health, education, and social welfare, and factors that bear on quality, availability, and accountability in public services. Includes balance between professional, bureaucratic, and political accountability, and client roles in service delivery. Open to qualified undergraduates.
M. Lipsky

17.235 Theories of Organizations

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

17.236 Theories of Organizations (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Considers the historical roots of modern administrative theory: the effect of technology on organizational structure and functions; how decisions are made within organizations, emphasizing cognitive bases for decision making; how actors in an organization's environment influence organizational behavior; the problem of executive control; the challenges of uncertainty and complexity for organizational performance. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.235. Consult Department headquarters.

American Politics

17.241 Introduction to the American Political Process

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Studies functioning of the American national governmental system, emphasizing the theoretical and historical background of the Constitution, the Congress, the President, and the Judiciary. Particular attention devoted to diffusion of power in national government, role of the political party, and how institutions of national government help fulfill the goals of a just and democratic society.
C. Stewart, R. M. Valelly

17.242 The International Sources of Domestic American Politics (A) (New)

Prereq.: Permission of Instructor
G (1)
3-0-9

Examines the impact of geopolitical conflict and of the international economy on domestic American politics and policy making from the antebellum era to the present, with emphasis on the period after World War II. Special attention paid to links between foreign policy and foreign economic policy and change and continuity in the organization of the legislative-executive system, interest group politics, political entrepreneurship, party politics, the organization of the media, and elite and citizen attitudes toward constitutionalism and social democracy.
R. M. Valelly

17.243 American Politics and Social Change

Prereq.: —
U (2) HUM-D **Next offered 1989-90**
3-0-9

Analyzes both industrialization and the civil rights movement in order to treat aspects of the American political process (interest group and party politics), key national institutions (the presidency and Congress), and differences between normal and transformative politics in America. Special attention is paid to democratic theory. Includes American political evolution, the nature of democracy, the role of interests and values in politics, political leadership, participation, social conflict, and social control.
R. M. Valelly

17.244 The Politics of Spending and Taxing (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

In recent years, the toughest questions in American politics have centered on economic questions: how much to tax, how much to spend, and how much to allocate to specific governmental programs. Students analyze the political processes involved in making these three decisions, by focusing on topics such as how voters, parties, and interest groups influence spending and taxing choices; budgetary politics within Congress, the bureaucracy, and the institutional presidency; the politics of budgetary reforms; and the problems of developing a coherent budgetary policy in a democracy.
C. Stewart

17.245 The Supreme Court and Constitutional Processes

Prereq.: —
U (2)
3-0-9

An interpretation of constitutional rights, processes, and concepts of limited government, in light of Supreme Court decisions and executive and legislative initiatives.
L. Menand

17.249 Electoral Politics in the US

Prereq.: 17.241
U (1) **Next offered 1989-90**
3-0-6

Analyzes political parties and their role in decision making in the political system. Primary attention to the American party system, national party organization, presidential nominating conventions, electoral strategies, and especially the dynamics of American voting behavior. Comparison with parties and electoral behavior in other political systems, especially those of Western Europe. Attention to extremist political movements and the behavior of electorates under acute stress.
W. D. Burnham

17.250 Theories of the American State (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Is there a "state" in America and how can it be conceptualized? What are the logics of its evolution? What consequences have patterns of evolution had for politics, economy, and society? Considers such questions, and addresses a recent and growing literature, including Skowronek, Skocpol, and others. Contrasts are drawn with pluralist and "rational choice" understandings of "the state." Open to undergraduates by permission of the instructor.
R. M. Valelly

17.251 Congress and the American Political System (Revised Unit)

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

17.252 Congress and the American Political System (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Focuses on both the internal processes of the House and Senate and on the place of Congress in the American political system. Attention to committee behavior, leadership patterns, and informal organization. Considers relations between Congress and other branches of government, as well as relations between the two houses of Congress itself. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.251.
C. Stewart

17.253 American Political Economy

Prereq.: 17.241
U (2)
3-0-9

17.254 American Political Economy (A)

Prereq.: 17.241
G (2)
3-0-9

Over time, what have been the key ways in which governmental institutions have regulated the national economy and the social effects of the economy's operation? With what consequences for efficiency, income equality, political participation, and political regime legitimacy? Special attention paid to political-party and interest-group systems, state structure, and state capacity. Graduate students pursue the subject in greater depth. Meets with 17.253.
R. M. Valelly

17.256 Topics in American Political Economy (A)

Prereq.: 17.241
G (2) **Next offered 1989-90**
3-0-9

Offers a view of the field as a whole for students without a special background. Considers classical and modern texts representing several influential but sharply contrasting approaches. Divergent methodological presuppositions and attitudes toward key terms such as "economics," "politics," and "history" in later works of these traditions are highlighted. Major American political institutions and processes are highlighted in the context of American political economy.
W. D. Burnham

17.257J American Society: Values, Institutions, and Variety

(Same subject as 11.006J)
Prereq.: —
U (2) HUM-D
3-0-9

See description under subject 11.006J.
G. T. Marx

17.258 Politics of Race and Ethnicity in America (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

17.259 Politics of Race and Ethnicity in America

Prereq.: —
U (2)
3-0-9

How have race and ethnicity shaped American politics from the 18th to the 20th centuries? What differences have they made to ideology and the historical development of the political economy, the party system, and the American state, and vice versa? Considers these questions, using a comparative perspective where appropriate. Graduate students expected to pursue the subject in greater depth through reading and individual research.
R. M. Valelly

17.260 Graduate Seminar in American Politics (A)

Prereq.: 17.241
G (1) **Next offered 1989-90**
3-0-9

Analyzes the American political system, with primary emphasis on the national level. Examines American political culture, Federalism, American party system, representation and public policy, and major institutional components of the national policy process. Attention to contemporary and comparative research on American politics and government. Discussion also includes some reference to the explicit and implicit theoretical assumptions of such work, as well as critiques of these assumptions.
W. D. Burnham

17.261 Congress and the Policy Process

Prereq.: —
U (2)
3-0-9

17.262 Congress and the Policy Process (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Analyzes the genesis and implementation of policy in the US by understanding the relations between Congress and other political entities — the presidency, the bureaucracy, the courts, and voters. Special attention is paid to the American system of weak parties and divided powers and how these peculiarities of institutional design leave their marks on the policy process within and between the national political institutions.
C. Stewart

17.264 Dynamics of Electoral Politics (A)

Prereq.: 17.241
G (2) **Next offered 1989-90**
3-0-9

Analyzes mass voting behavior in the US, past and present. Evaluates leading theories of American electoral politics in light of inferences from data analysis. Emphasizes longitudinal system dynamics and other properties, both quantitative and nonquantitative. Some comparative analysis of electoral dynamics and theories of electoral politics in other Western political systems. Attention to American voting behavior since 1960.
W. D. Burnham

17.265 Congressional Elections

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

Examines both the dynamics of congressional elections themselves, as well as the normative and policy consequence of electoral politics. Includes candidate recruitment; campaign strategy; contributions; the role of parties; voters' behavior; national politics and congressional elections; and the policy consequences of electoral arrangements. Where appropriate, activity in or analysis of local campaigns is included as a class requirement.
C. Stewart

17.267 The President

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

The US President as constitutional executive; sharer of governing authority with Congress and the courts; party leader; chief manager of executive agencies; foreign policy leader; and focus for national political, economic, and social aspirations. Is the modern office of the President compatible with democratic traditions and the traditional rule of law? Consult Department headquarters.

17.269 Presidential Elections

Prereq.: —
U (1) **Not to be offered 1989-90**
3-3-6

Examines the dynamics of presidential elections: events preceding the primaries, the conduct of the general election itself, and the policy consequences of the electoral process. An important aspect of this course is participation in the primary campaign of a candidate chosen by the student. Aside from direct participation in a campaign, topics covered by the course include the participants themselves (candidates, voters, parties, consultants, the Electoral College), campaign resources (money, information, media attention), the major campaign events (primaries, conventions, general election), and prospects for reform.
C. Stewart

17.270 Evolution of American Politics (A)

Prereq.: —
G (1)
3-0-9

17.271 Evolution of American Politics

Prereq.: 17.241
U (1)
3-0-6

Provides students with historical background for understanding growth and change in American national political structures and processes to their present state. Orients the approach at least as much to social science perspectives as to those of more conventional history. Topics: the evolution of Congress, the presidency, and electoral politics, with attention to changes in behavior, structure, and performance. Emphasizes developments in the 20th century. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.270. Consult Department headquarters.

17.272 Mass Political Organization (A)

Prereq.: —
G (2)
3-0-9

Why do people join mass political organizations such as social movements, interest groups, and urban political machines? What accounts for their continued participation and for the ultimate success or failure of these organizations? These questions are explored in light of competing theories of mass participation and organizational dynamics. How do mass political organizations balance needs of members with competing demands associated with effectiveness?
M. Lipsky

See also 17.702, 17.704. 17.707J, 17.720

Science, Technology, and Policy

17.301 Science, Technology, and Politics

Prereq.: —
U (2)
3-0-6

17.302 Science, Technology, and Politics (A)

Prereq.: —
G (2)
3-0-9

Examines the impacts of science and technology on governmental institutions and processes. Includes extent to which science and technology have transformed fundamental political institutions and relationships, role of scientists and engineers in political decision making, societal mechanisms for reaching decisions on controversial technological issues, and impact of science and technology on foreign policy and international political relationships. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.301.
H. M. Sapolsky

17.306J Special Topics in Science, Technology, and Public Policy (A)

(Same subject as STS 503J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Workshop exploring special topics in science, technology, and public policy related to research interests of participating faculty and visiting speakers. Student papers are presented in the latter part of semester. Intended to provide an overview of the general interaction of science, technology, and goverment.
H. M. Sapolsky, C. Kaysen, E. B. Skolnikoff

17.322 Seminar in Systematic Policy Analysis and Technology Assessment (A)

Prereq.: 14.01, 14.02
G (2) **Next offered 1989-90**
3-0-6

Analyzes policy problems illustrative of those facing the Federal and local governments. Cost-benefit calculations and topics in welfare economics. Cases selected from such areas as energy policy, the environment, space programs, and communications. Open to undergraduates by permission of instructor only.
G. W. Rathjens

17.328 Science and Technology in International Affairs (A)

Prereq.: 17.302 or Permission of Instructor
G (1)
3-0-9

Explores the roles of science and technology and their impact in the international political system, and process by which foreign policy involving science and technology is made in the US and internationally. Provides an overview of major international political effects and develops the role of science and technology in a few issue-areas in some detail: East-West transfer of technology, international cooperation, national security, international organizations, bilateral relations, and a selection of others.
E. B. Skolnikoff

17.334J International Air Transportation

(Same subject as 16.752J)
Prereq.: —
G (1)
3-0-6

See description under subject 16.752J.
B. R. Gidwitz

17.336J Social and Political Implications of Science

(Same subject as STS 105J)
Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
2-0-10

See description under subject STS 105J. Consult K. Keniston.

International Relations/Arms Control and Defense Studies

International Relations and Foreign Policy

17.403 American Foreign Policy in a Changing World

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

The US as a major actor in a fast-changing world. Lectures and discussions focusing on the roots of US foreign policy; origins of the Cold War; the age of intervention; security redefined; interdependence; future options.
L. P. Bloomfield

17.405 Seminar in Middle Eastern Politics

Prereq.: —
U (1)
3-0-6

17.406 Seminar in Middle Eastern Politics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Divided into three parts: 1) domestic and regional politics of the Arab East, Iran and the Gulf, the Maghreb, and Israel; 2) energy: the world oil and energy picture; 3) Middle East and world politics: the East-West conflict, the Arab-Israeli conflict, the Iran-Iraq war, and their interaction with energy problems. Lectures, discussions, and a paper or a take-home examination. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.405.
W. E. Griffith, N. Choucri

17.407 International Relations: War and Peace

Prereq.: 17.403
U (2)
3-0-6

Analyzes the study of real and potential international systems. Topics: international warfare, the impact of technology on war and the arms race, the balance of power, classical and modern imperialisms, regional and universal international organizations. View of alternative futures examined for developed and developing worlds. Previous study of international relations expected.
S. E. Miller

17.420 Theories of International Relations (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Review and critical discussion of the literature of international relations. Focuses on alternative paradigms, world views, and middle-range theories, including political realism, idealism, systems theory, Marxism, peace research, and alternative theories from non-Western, non-major-power perspectives. Open to undergraduates by permission of instructor only.
H. R. Alker, Jr.

17.422 International Political Economy (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Interdisciplinary analysis of ways in which nations undertake dual international objectives: pursuit of power and pursuit of wealth. Surveys major competing paradigms of international political economy, including neoclassical economics, Marxist and neo-Marxist theories, dependency theses, and structural European views of power relations. Examines political and economic dimensions of international trade, capital flows, foreign investment, and military and strategic policies. Reviews the evolution of international economic organizations and political implications.
N. Choucri

17.423 Conflict and Its Resolution (New)

Prereq.: 17.203
U (1)
3-0-9

17.424 Conflict and Its Resolution (A)

Prereq.: 17.842
G (1)
3-0-9

Focus is on different, empirically oriented approaches to international conflict and its resolution. Topics include the sources, instrumentalities, and modalities of conflict, and the ways in which conflict is negotiated, managed, or resolved. Both the research conceptualization (its theoretical and paradigmatic roots), research design (including the continuum from experimental to quasi-experimental to nonexperimental options), and the methodological implementation of various empirical studies are reviewed. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.423.
H. R. Alker, Jr.

17.428 US Foreign Policy — Past, Present, Future (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Critical analysis of US foreign policy in the context of past tendencies and future possibilities. Roots of US policy; origins of the Cold War; the "Age of Intervention"; security redefined; interdependence; future options. Open to advanced undergraduates by permission of instructor only.
L. P. Bloomfield

17.430 The Foreign Policy Process (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

The planning and execution of foreign policy in the US (and, where data available, other countries). Relevant organizational and decision-making models and theories critically analyzed. The President and Congress, NSC and State Department, and system weaknesses. Policy planning, crisis behavior, and issues of irrationality. Simulation and other techniques. Student-run planning game. Open to advanced undergraduates by permission of instructor only.
L. P. Bloomfield

17.438 Research Seminar on African Foreign Relations and Development (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Special topics concerning African international relations, including US relations with Southern Africa, African international organizations, and African participation in multilateral organizations. Development problems of selected African countries. Intensive examination of a sector, institutional factor, or process. Examples include agricultural development, the parastatal sector, regional integration, international investment institutions.
W. R. Johnson

Defense and Arms Control Studies

17.460 Defense Politics (A)

Prereq.: —
G (2)
3-0-9

Examines the politics affecting US defense policies. Includes consideration of intra- and inter-service rivalries, civil-military relations, contractor influences, congressional oversight, and peace movements in historical and contemporary perspectives.
H. M. Sapolsky

17.462 Statecraft, Strategy, and War (A)

Prereq.: —
G (1)
3-0-9

Introduction to major thinkers and major issues relating to war as an instrument of state policy. Emphasizes strategy, deterrence, and problems of managing force effectively. Provides a representative sampling of the most significant work on these subjects.
S. E. Miller

17.464 Theory and Politics of Arms Control (A)

Prereq.: 17.486, 17.490
G (2)
3-0-6

The evolution of arms control and disarmament policy and approaches. Critical review of the major negotiating efforts and agreements, including consideration of domestic political factors.
S. E. Miller

17.465 Nuclear War: Threat and Avoidance

Prereq.: —
U (2) HASS
3-0-6

Engineering School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, J. P. Ruina

17.466 Seminar in Arms Control and Defense Policy (A)

Prereq.: 17.486, 17.490, 17.464
G (2)
3-0-6

Assessment of post-World War II arms control efforts and major issues in defense policy. Emphasis on current issues. Topics, varying from year to year, treated in some detail. Consideration of technical questions, political questions, economic and military impact. Examples: missile deployment in Europe and the INF negotiations, START, and space-based ballistic missile defense.
G. W. Rathjens, J. P. Ruina

17.468 Foundations of Security Studies (A)

Prereq.: —
G (2)
3-0-9

Aims to develop a working knowledge of the theories and conceptual frameworks that form the intellectual basis of security studies as an academic discipline. Particular emphasis on balance of power theory, organization theory, civil-military relations, and the relationship between war and politics. The reading list includes Jervis, Schelling, Waltz, Blainey, von Clausewitz, Brodie, Allison, Steinbruner, and Huntington. Students write a seminar paper in which theoretical insights are systematically applied to a current security issue.
B. Posen

17.469 Military Forces and Foreign Policy

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

17.470 Military Forces and Foreign Policy (A)

Prereq.: —
G (1) **Next offered 1989-90**
3-0-9

A comparative examination of US and Soviet defense policies, foreign policies, and the use of their military forces in the postwar period. Analyzes 20 historical cases involving deterrence of central war, coercive diplomacy, crisis management, and limited intervention. Discusses implications for military force posture planning and military strategy. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.469.
S. M. Meyer

17.472 American Security in the Nuclear Age

Prereq.: —
G (1) **Next offered 1989-90**
3-0-9

17.473 American Security in the Nuclear Age

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Surveys the evolution of American security policy since World War II. Includes the postwar demobilization, the assumption of global responsibilities, the Korean War rearmament, the nuclearization of American defense in the 1950s, the McNamara revolution, Vietnam and the problem of intervention, the Nixon doctrine, and current defense policy issues. Focuses on the problems of matching capabilities to commitments. Graduate students are expected to pursue the subject at greater depth through reading and individual research.
S. E. Miller

17.474 Comparative Defense Management (A)

Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

Examines the management issues in the organization, equipping, and direction of military forces. Of particular interest is the weapon acquisition process — its politics, administration, and effects. Comparisons made with European, Israeli, and Soviet experience.
H. M. Sapolsky

17.476 Strategic Nuclear Forces Seminar (A) (New)

Prereq.: —
G (1)
3-0-9

Introduces the assessment of strategic nuclear forces. Emphasizes the development of force requirements and methods for analyzing alternative force postures in terms of missions, effectiveness, and cost. The history of the US-Soviet strategic competition provides the backdrop against which the evolution of nuclear strategy and forces is considered.
S. M. Meyer

17.482 US General-Purpose Forces (A)

Prereq.: —
G (2)
3-0-9

17.483 US General-Purpose Forces

Prereq.: —
U (2)
3-0-9

Based on the concept of Grand Strategy as a system of interconnected political and military means and ends. Topics covered include US grand strategy, the organization of the US military, the defense budget, ground forces, tactical air forces, naval forces, power projection forces, and the control of escalation. Particular episodes of military history that offer insights into current conventional forces issues examined. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.482.
B. Posen

17.484 Comparative Grand Strategy and Military Doctrine (A)

Prereq.: —
G (1)
3-0-9

A comparative study of the grand strategies and military doctrines of the great powers in Europe (Britain, France, Germany, and Russia) from the late 19th to the mid-20th century. Examines strategic developments in the years preceding and during World Wars I and II. What factors have exerted the greatest influence on national strategies? How may the quality of a grand strategy be judged? What consequences seem to follow from grand strategies of different types? Open to undergraduates with permission of instructor.
B. Posen

17.486 Nuclear Weapons and Arms Control: Technology and Policy Issues

Prereq.: —
G (1)
4-0-8

Engineering School-Wide Elective Subject. Description given at end of this chapter on SWE page.
G. W. Rathjens, J. P. Ruina

17.487 Quantitative Approaches to Defense Problems

Prereq.: 17.465, 17.842
U (1)
3-0-6

17.488 Quantitative Approaches to Defense Problems (A)

Prereq.: 17.486, 17.465 or 17.842
G (1)
3-0-6

Systems analysis of policy choices in the defense/arms control area. Consideration of cost and benefit criteria. Analytical approaches and critique of applications.
G. W. Rathjens

17.490 Soviet Defense Planning (A)

Prereq.: —
G (1) **Next offered 1989-90**
3-0-9

Examines the political, economic, and military determinants of Soviet military policy. Soviet military doctrine, strategy, organization, and weapons procurement are studied from the perspective of Soviet defense planners.
S. M. Meyer

17.492 Research Seminar in Soviet Security Studies (A)

Prereq.: 17.490
G (1, 2)
3-0-9

An advanced seminar that examines historical and contemporary issues in Soviet defense planning. Students select individual research topics and work with original source materials.
S. M. Meyer

17.496 Seminar on European Security (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

MBFR negotiations; development of new weapons systems (SS-20, Pershing 2, Cruise Missile); differing West European and US estimates of the USSR and their policy results (credits, technology transfer, and arms control negotiations); the INF treaty, the energy crisis, foreign trade, and US-West European differences on Middle Eastern policy.
W. E. Griffith

See also 17.301, 17.302, 17.328, 17.403, 17.405, 17.406, 17.407, 17.420, 17.428, 17.430.

Comparative Politics/Political Development/Communist Studies

Theories and Research Methods

17.510 Field Seminar in Comparative Politics (A)

(17.588)
Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

Review of concepts, methods, and major works in selected areas of comparative politics. Particularly intended for graduate students planning General Exams in comparative politics, but open to anyone with experience in one or more relevant fields. Substantial reading and short papers. Lectures by various faculty members on such topics as intellectual history of the field, political culture, political parties, communist studies, public policy, development, participation, political economy.
D. L. M. Blackmer, Staff

17.512 Theories of Political Development (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
3-0-9

Studies analytical models of the political process in transitional societies. Systematic examination of factors influencing political behavior in changing societies; functions of politics in such societies. Open to qualified undergraduates.
L. W. Pye

17.520 Comparative Politics of Business-Government Relations (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Seminar provides an introduction to the cross-national study of business-government relations, emphasizing competing theoretical perspectives and with attention to experiences of selected industrialized countries. Examines how and why governments are in business, as well as the influence businesses exert on governmental decision making. Central questions include historical impact of business on national economies, political origins of state enterprises, and implications of business-government relations for democratic theory.
R. J. Samuels

17.522 Research Seminar on African Development (A)

Prereq.: 17.576
G (2)
3-0-9

Research seminar on particular development problems of selected African countries. Intensive examination of a sector, institutional factor, or process. Examples include agricultural development, the parastatal sector, regional integration, international investment institutions.
W. R. Johnson

See also 17.154J, 17.156J.

Advanced Industrial Societies

17.530 The Politics of the Federal Republic of Germany

Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

Survey of the principal domestic and foreign policy issues in the Federal Republic. After a brief historical survey and a study of the Adenauer period, emphasis on the period after 1969: party system, economic factors, the media, religion, and the new left; relations with the US, France, and Ostopolitik toward the USSR, Poland, Hungary, and the GDR. Open to qualified undergraduates.
W. E. Griffith

17.534 Domestic Politics of Western Europe (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Compares politics and society in France, Great Britain, Germany, and Italy. Analyzes "cases" of the integration of feudal remnants and the problem of controlling the economy. Open to undergraduates.
S. Berger

17.539 Politics and Policy in Contemporary Japan

Prereq.: —
U (2)
3-0-6

17.540 Politics and Policy in Contemporary Japan (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Analyzes contemporary Japanese politics, focusing primarily upon the post-World War II period. Includes examination of the dominant approaches to Japanese politics and society, the structure of the party system, the role of political opposition, the policy process, foreign affairs, and interest groups. Attention to defense, foreign, industrial, social, energy, technology policy processes. Graduate students are expected to pursue the subject at greater depth through reading and class presentations. Meets with 17.539.
R. J. Samuels

See also 17.154J, 17.156J, 17.158, 17.164, 17.166J.

Developing Countries

17.543 Political Change in Latin America

Prereq.: —
U (1) HUM-D **Next offered 1989-90**
3-0-9

Introduction to the dynamics of political change in Latin America today. Emphasis on the conflict between democracy and authoritarianism, the relationship between economic and political change, and the process of empowerment of excluded social groups. Special attention to the Central American conflict, international debt, the environment, and the role of women.
J. A. Fox

17.544 Comparative Politics of Latin America (A)

Prereq.: —
G (2)
3-0-9

Latin American politics in comparative perspective. Focus on conflict between democracy and authoritarianism. Case studies of different political systems and economic models, such as Mexico, Brazil, Chile, Cuba, and Central America. Special attention to regime change, social movements, economic policy making, and the role of the US.
J. A. Fox

17.545 Political Change in South Asia: India, Pakistan, Bangladesh, and Afghanistan

Prereq.: —
U (2)
3-0-9

17.546 Political Change in South Asia: India, Pakistan, Bangladesh, and Afghanistan (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Examines the major political changes occurring in the region: the changing role of political parties and the military; the impact of caste, linguistic, religious, tribal, and class forces; the electoral process; the political determinants and consequences of development policies; and the changing involvement of external powers. Attention to issues of national integration, political legitimacy, and political participation. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.545.
M. Weiner

17.547 Chinese Politics

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

17.548 Chinese Politics (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-6

Analyzes contemporary Chinese politics, both pre-Communist and Communist. Focus on the process of modernization and political development of Chinese civilization. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.547.
L. W. Pye

17.558J Politics, Technology, and Development in the Middle East (A)

(Same subject as 1.255J, 4.715J, 11.488J, 21.485J, STS 509J)
Prereq.: —
G (1)
3-0-9

Focuses on contemporary conflicts and competing ideologies, Islam and politics, colonial experiences, and patterns of social pressures. Examines role of technological and scientific institutions. Changing environment of international business is explored, as are patterns of investments in the region. Provides students with interdisciplinary approach to development in the Middle East. Open to undergraduates with permission of instructor.
N. Choucri, F. Moavenzadeh, R. Lewcock, K. Keniston

17.560J Technology, Business, and Public Policy in the Middle East (A)

(Same subject as 1.256J, 4.716J, 11.489J)
Prereq.: —
G (2)
3-0-9

Focuses on the role of the state, political, and economic aspects of oil price changes, technological development, economics of exhaustible resources, and infrastructure development. Special emphasis on technology transfer and manpower development. Examines capital flows and foreign exchange markets, as well as prospects for the multinational firm in the Middle East. Provides students with interdisciplinary approach to development in the Middle East. Open to undergraduates with permission of instructor.
N. Choucri, F. Moavenzadeh, L. Trilling, W. Porter

17.562J Modern Egypt and Iran: Islam and Politics in Historical Perspective (A)

(Same subject as 21.484J)
Prereq.: —
G (2) HASS
3-0-9

See description under subject 21.484J. Open to undergraduates.
P. S. Khoury

17.576 Politics of Development and Underdevelopment in Africa (A)

Prereq.: —
G (1)
3-0-9

Analyzes development issues and policies in selected African countries (*inter alia*, Cameroon, Kenya, Nigeria, Tanzania) including a consideration of the nature and functioning of the political systems in these states, their interaction with the environment of other states, international organizations, and multinational corporations. Emphasizes policies being pursued by the government to promote economics and social development. Includes role of governmental and voluntary organizations. Considers major theoretical literature on development relevant to Africa.
W. R. Johnson

17.577 The Politics of Change in the Third World (New)

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Introduction to the politics of the Third World development process, focusing on ideas, choices, structures, and constraints. Emphasis on the central role of governments in charting development paths, as well as the multiple forces for change which emerge from below. Practical policy problems dealt with include hunger, the environment, health, population, urbanization, technology transfer, and foreign aid.
J. A. Fox, W. R. Johnson

See also 17.406, 17.438

17.590 Research Seminar on Latin American Politics

Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

For students planning research in Latin America, and for students who seek to incorporate Latin American cases in comparative frameworks. Discussion of current work in the field, with emphasis on sources, methodology, and strategies for testing theory. Presentation of students' research projects as appropriate.
J. A. Fox

See also 17.168, 17.170.

Communist Studies

17.602 Continuity and Change in Soviet Politics (A)

Prereq.: —
G (1)
3-0-9

17.603 Continuity and Change in Soviet Politics

Prereq.: —
U (1)
3-0-9

Analysis of the nature and evolution of Soviet politics, centered on four topics: 1) Lenin's theory and practice in creating the Bolshevik party and seizing power; 2) competing responses to the economic and political dilemmas of building a socialist regime in a peasant society, 1917-1928; 3) origins and impact of Stalin's totalitarian system; 4) Soviet politics since Stalin. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.602.
D. L. M. Blackmer

17.604 Topics in Soviet Foreign Policy (A)
(New)

Prereq.: —
G (1)
3-0-9

Treats contemporary Soviet foreign policy by regional areas, not chronologically. After a very brief historical background, the course is divided into three areas: policy toward the West (and Japan), policy toward other communist states and parties (centering on Sino-Soviet relations), and policy toward the Third World. A substantial paper or a take-home examination. Open to undergraduates with the permission of the instructor.
W. E. Griffith

17.606 The Politics of Communist States and Parties in Eastern and Western Europe (A)

Prereq.: —
G (2)
3-0-9

Primarily an analysis of the domestic problems and foreign relations of the Communist states of East Europe since World War II, followed by a survey of the domestic and foreign policies of the major West European Communist parties. Open to qualified undergraduates.
W. E. Griffith

17.608 Radical and Revolutionary Ideologies (A)

Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

Consecutive treatment of background of Marxism in German idealist philosophy; Marx, Engels, Bakunin, and Anarchism; the revisionists, orthodox Marxists, leftist Marxists, origins of Russian radicalism and Marxism; Lenin, Trotsky, Bukharin, Stalin; Fascism; the Western-Marxists; Titoism; East-European revisionism; Maoism; ideology in Sino-Soviet split; radicalism in Cuba; Chinese Cultural Revolution; Asian and African Socialism; North Vietnam; Radicalism and the New Left in North American and Western Europe; Eurocommunism; Gorbachev's and Deng's ideologies. Open to qualified undergraduates.
W. E. Griffith

17.609J Seminar in the Historical and Political Evolution of the Soviet Union

(Same subject as 21.378J)
Prereq.: Permission of Instructor
U (2)
3-0-6

17.610 Seminar in the Historical and Political Evolution of the Soviet Union

Prereq.: Permission of Instructor
G (2)
3-0-9

Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.609J. See description under subject 21.378J.
L. R. Graham

17.612 The Soviet Political System (A)

Prereq.: 17.602
G (2) **Next offered 1989-90**
3-0-9

Research seminar on the Soviet political system, with special emphasis on the period since Stalin's death. Three main objectives: 1) evaluation of competing interpretations of Soviet politics, including efforts to apply to the Soviet Union concepts derived from the study of other political systems; 2) discussion of major issues in contemporary Soviet politics; 3) student research.
D. L. M. Blackmer

17.614J Russian Science and Society

(Same subject as STS 103J)
Prereq.: —
G (2)
3-0-9

See description under subject STS 212J.
L. R. Graham

17.618 The Theory and Practice of Decision Making in the USSR (A)

Prereq.: —
G (2)
3-0-9

Explores the leading theories of decision making and their application to contemporary Soviet policy formulation and implementation. Beyond rational choice and strategic planning, bureaucratic, organizational, and other contending frameworks are examined. Cases include defense, foreign policy, and economic and industrial policies. Previous study of Soviet politics and institutions is expected.
S. M. Meyer

See also 17.490.

Political Communication/ Political Behavior

17.702 Political Behavior and American Politics (A)

Prereq.: —
G (1)
3-0-9

Reviews the behavioral perspective in the study of American politics. Includes analysis of political ideology in mass publics, issue voting, political communication, political psychology, and the interplay of economic interests and political participation. Open to qualified undergraduates.
P. H. Lemieux

17.704J Political Psychology and Behavior (A)

(Same subject as STS 508J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Basic survey of individual and group psychology in relation to political behavior. Readings cover the intellectual development of political psychology, with stress on individual emotional growth and motivations, attitude formation and change, leadership styles, mass behavior, and political culture.
L. W. Pye, K. Keniston

17.706J Social Movements (A)

(Same subject as 11.515J)
Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

Considers the origins, ideology, social basis, mobilization, tactics, and consequences of modern American and European social movements. The focus is on the basic theories, concepts, and methods needed to understand social movements and their political impact. Examples are drawn primarily from recent US and European civil rights, student, women's, environmental, and anti-democratic movements.
G. T. Marx

17.707 Mass Communication and American Culture

Prereq.: —
U (2) HUM-D **Next offered 1989-90**
3-0-6

Studies emergence of the modern media of mass communication and their influence in shaping the individual's values and knowledge of world events. Topics: political control through mass communication, violence, racial and sex role stereotypes, popular culture, and future communication technologies. Consult Department headquarters.

17.720 Communication and Public Opinion (A)

Prereq.: —
G (2) **Next offered 1989-90**
3-0-9

How is the political culture produced? What is the role of the mass media in the process? How does the organization of the media affect what is produced? How is it different in societies without modern mass-media systems? How does the symbolic content of the media shape political discourse? What are the cognitive processes underlying the formation of public opinion? What is the role of ideology? How do interpersonal processes interact with media content in shaping thinking about political issues?
P. H. Lemieux

17.726 Political Culture (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Analyzes the psychological and attitudinal bases of politics. Special emphasis on socialization patterns, styles of politics, and elite operational codes. Open to qualified undergraduates.
L. W. Pye

See also 17.255, 17.257J, 17.264, 17.814.

Polimetrics/Models and Methods

17.803 Debates and Arguments

Prereq.: —
U (1) **Next offered 1989-90**
2-1-9

Examines the fallacies and logics of a variety of recent liberal, radical, and conservative political arguments. Specific attention given to psychologics characteristic of "ideological" political arguments, democratic theory, Marxian dialectical reasoning, and the structure of legal debate. The laboratory includes debating exercises and logical and computerized analysis of various political arguments.
H. R. Alker, Jr.

17.812 Qualitative Research Strategies (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
2-2-8

Introduces a variety of qualitative research strategies and methods appropriate for studying organizations and bureaucracies, professions, social movements, and other phenomena amenable to field research. Considers the theory of comparative research and methods, including the case-study approach, documentary analysis, interviewing techniques, participant observation, and evaluation methodologies. Presents materials that illustrate sound use of such methods, as well as their limitations.
M. Lipsky

17.814 Research Methods in Political Behavior (A)

Prereq.: Permission of Instructor
G (2)
2-2-8

Basic principles of research methodology for the testing and refinement of social science theory in the areas of political behavior, political sociology, social psychology, and communications. Includes survey design and analysis, experimental research, content analysis, and field research.
P. H. Lemieux

17.816 Field Research Methods in Comparative Politics and Political Development (A)

Prereq.: Permission of Instructor
G (1)
2-2-8

Introduces a variety of approaches and methods for conducting research in Western Europe and developing countries, including elite interviewing, participant observation, case studies, cross-cultural survey research, and documentary research. Attention to conceptual, practical, and ethical issues of conducting research abroad, e.g., the role of language in social research, the limits and uses of official sources, and ethical responsibilities of social scientists. Not open to first-year graduate students.
M. Weiner

17.820 Quantitative Methods in American Politics (A)

Prereq.: —
G (2) **Next offered 1989-90**
2-2-8

Examines major quantitative research techniques used by political scientists to investigate American mass political and institutional behavior. Substantive topics covered include the specification and examination of voting and opinion models, models of legislative behavior, and budgetary decision making.
C. Stewart

17.842 Quantitative Research in Political Science and Public Policy (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

An introduction to the application of elementary statistics to political analysis. A basic literacy subject, teaching the student how to read and interpret the quantitative literature in various subfields of political science and public policy. Students develop elementary statistical computation skills and learn to use a statistical computing package.
P. H. Lemieux

17.846 Multivariate Political Analysis (A)

Prereq.: Permission of Instructor
G (2)
2-2-8

Focus on multivariate data analysis procedures, emphasizing regression. Includes dummy variable regression, distributed lags, and instrumental variables. Students must have taken at least one previous subject in statistics. Open to qualified undergraduates.
P. H. Lemieux

17.848 Complex Models of Social Systems (A)

Prereq.: 6.001 or 17.842
G (2) **Next offered 1989-90**
Arr.

Research seminar focuses on complex models of socio-political processes. The emphasis this year is on political reasoning processes. Discusses models from biological, linguistic, logical, semiotical, and artificial intelligence traditions.
H. R. Alker, Jr.

17.850 Advanced Topics in Statistical Modeling (A)

Prereq.: 17.846
G (2) **Next offered 1989-90**
3-0-6

Focuses on selected topics in statistical modeling and data-based simulation, including ARIMA models, intervention analysis, analytical vs numerical techniques of dynamic analysis, nonlinear estimation methods. Emphasizes political science applications. Open to undergraduates by permission of instructor.
P. Lemieux

See also 17.322, 17.487, 17.488.

General Subjects

17.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in Political Science in theoretical and applied research. For further information, contact the Departmental Coordinator.
D. L. M. Blackmer, S. Berger

17.901 Independent Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Independent research enabling students to do work in an agency, state, or local government, or other public organization. The academic component involves close contact between the student and a faculty advisor and written work. Work may be done during the summer. Admission by arrangement with individual faculty member.
D. L. M. Blackmer, S. Berger

17.905-17.911 Reading Seminar in Social Science

Prereq.: —
U (1, 2)
Arr.

Reading and discussion of special topics in the fields of social science. Open to advanced undergraduates by arrangement with individual staff members. 17.909 is taught P/F.
D. L. M. Blackmer, S. Berger

17.912 Junior Colloquium in Political Science and Public Affairs (New)

Prereq.: Two Political Science subjects or Permission of Instructor
U (2)
2-0-10

Seminar identifies, explores contributions of political science to critical issues in US and world affairs. Designed to help departmental majors and minors understand the way political scientists choose and ask questions and seek answers to those questions. Topics include ethnicity and politics, technology and policy, industrial policy, international political economy, wars today, and regional powers.
R. J. Samuels

17.913 Pre-thesis Reading Seminar

Prereq.: —
U (1, 2) [P/F]
3-0-6

Intensive reading on topics of interest to students preparing for senior thesis under guidance of thesis supervisor. A written paper required, forming a substantial part of the senior thesis.
D. L. M. Blackmer, S. Berger

17.ThU Undergraduate Political Science Thesis

Prereq.: —
U (1, 2)
Arr.

Program of undergraduate research, leading to the writing of an S.B. thesis. To be arranged by the student under approved supervision.
D. L. M. Blackmer, S. Berger

17.950-17.960 Reading Seminar in Social Science (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Reading and discussion of special topics in the fields of social science. Open to advanced graduate students by arrangement with individual staff members. 17.959 is taught P/F.
D. L. M. Blackmer, S. Berger

17.ThG Graduate Political Science Thesis (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Program of graduate research and writing of thesis; to be arranged by the student with supervising committee.
D. L. M. Blackmer, S. Berger

Course 18 Mathematics

General Mathematics

18.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in mathematics. Permission required in advance to register for this subject. For further information, consult the Departmental Coordinator.
D. S. Jerison, Staff

18.01 Calculus

Prereq.: —
U (1, 2)
5-0-7

Differentiation and integration of functions of one variable, with applications. Concepts of function, limits, and continuity. Differentiation rules, application to graphing, rates, approximations, and extremum problems. Mean-value theorem. Definite and indefinite integration. Fundamental theorem of calculus. Applications of integration to geometry and science. Elementary functions. Techniques of integration. Approximation of definite integrals, improper integrals, and l'Hôpital's rule.
D. A. Vogan

18.011 Calculus

Prereq.: Assumes substantial prior knowledge of calculus
U (1)
5-0-7

Calculus of one variable, emphasizing applications. Quick review of differentiation, followed by intensive study of integration and infinite series, including, as time permits, special topics selected from: perturbation and iteration procedures, stability, summation techniques, asymptotics, numerical analysis, and other techniques. Practice in mathematical formulation of scientific problems and approximate methods of solution.
D. J. Benney

18.012 Calculus with Theory

Prereq.: —
U (1)
5-0-7

Covers the same material as 18.01, but at a deeper and more rigorous level. Emphasizes careful reasoning and understanding of proofs. Assumes knowledge of elementary calculus. Topics: axioms for the real numbers; the Riemann integral; limits, theorems on continuous functions; derivatives of functions of one variable; the fundamental theorems of calculus; Taylor's theorem; infinite series, power series, rigorous treatment of the elementary functions.
J. R. Munkres

18.013 Calculus with Applications

Prereq.: Assumes some prior knowledge of calculus
U (1)
5-0-7

1988-89: Offered as 18.011; see 18.011 description. Students wishing to take this course should register for 18.011.
D. J. Benney

18.02 Calculus

Prereq.: 18.01 or 18.011 or 18.012 or 18.013
U (1, 2)
5-0-7

Calculus of several variables. Vector algebra in 3-space, determinants, matrices. Vector-valued functions of one variable, space motion. Scalar functions of several variables: partial differentiation, gradient, approximation techniques. Multiple integrals with applications. Vector fields, line and surface integrals, exact differentials, Green's theorem, Divergence Theorem, Stokes's Theorem. Additional topics: linear algebra (term 1), infinite series (term 2).
Term 1: *H. Rogers, Jr.*
Term 2: *A. P. Mattuck*

18.021 Calculus

Prereq.: 18.011
U (2)
5-0-7

Continues 18.011. Calculus of several variables. Vector algebra, analytic geometry, planetary motion, orbit stability, partial differentiation, functions of several variables. Taylor series, extremal problems, linear programming examples, numerical methods, multiple integrals, approximate and asymptotic methods of evaluation, applications, vector calculus, gradient, curl, theorems of Stokes, Green, and Gauss, conservation laws, fluid motion.
H. P. Greenspan

18.022 Calculus with Theory

Prereq.: 18.012
U (2)
5-0-7

Continues 18.012. Parallel to 18.02, but at a deeper level, emphasizing careful reasoning and understanding of proofs. Considerable emphasis on linear algebra and vector integral calculus.
M. J. Dyer

18.023 Calculus with Applications

Prereq.: 18.013 or 18.01 or 18.011 or 18.012
U (1, 2)
5-0-7

1988-89: Offered as 18.021; see 18.021 description. Students wishing to take this course should register for 18.021.
H. P. Greenspan

18.03 Differential Equations

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1, 2, S) SD
4-0-8

Examples of initial-value problems in science and engineering associated with single equations and systems of first-order equations. Methods of solution include graphical constructions, series, Laplace transforms, matrices, numerical integration and the phase plane. Emphasizes formulation of natural phenomena in terms of differential equations and interpretation of the solutions.
Term 1: *G-C. Rota, R. R. Rosales*
Term 2: *A. Toomre, Staff*

18.04 Complex Variables with Applications

Prereq.: 18.03
U (1, 2)
4-0-8

Complex algebra and functions; analyticity; contour integration, Cauchy's theorem; singularities, Taylor and Laurent series; residues, evaluation of integrals; multivalued functions, potential theory in two dimensions; Fourier analysis and Laplace transforms. 18.04 and 18.075 may not both be taken for credit.
Term 1: *C. F. Pearson*
Term 2: *Staff*

18.05 Introduction to Probability and Statistics

Prereq.: 18.01 or 18.011 or 18.012 or 18.013
U (1, 2) SD
4-0-8

Elementary introduction, with applications to the social, physical, and life sciences. Relative frequency. Probability models. Combinatorics. Binomial and Poisson experiments. Normal approximation. Descriptive level of significance. Composite models. Chi-square approximation. Contingency tables. Hypothesis testing. Confidence regions. Random variables. Normal distribution methods.
Term 1: *R. M. Dudley*
Term 2: *M. Fygenson*

18.06 Linear Algebra

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1, 2, S) SD
3-0-9

Basic subject on matrix theory and linear algebra, emphasizing topics useful in other disciplines, including systems of equations, vector spaces, determinants, eigenvalues, similarity, positive definite matrices. Applications to Gauss elimination with pivoting, least-squares approximations, stability of differential equations, linear programming, and game theory. Compared with 18.710, more emphasis on matrix calculations and applications. Information: G. Strang.

18.063 Introduction to Algebraic Systems

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1) SD
4-0-8

Introduction to algebraic systems, primarily for students interested in computer and information sciences, with emphasis on finite systems. Reviews elementary set theory, natural numbers, modular arithmetic, induction, counting arguments. Elementary number theory and group theory. Applications to fast arithmetic, cryptography, combinatorics. Elementary graph theory. Introduction to rings and fields. Finite fields: coding theory, Hamming and BCH codes.
A. P. Mattuck

18.075 Advanced Calculus for Engineers (A except II, VI, VIII, XII, XIII, XVI, XVIII, XXII)

Prereq.: 18.03
G (1, 2, S)
3-0-9

Functions of a complex variable; calculus of residues. Ordinary differential equations; integration by power series; Bessel and Legendre functions. Expansion in series of orthogonal functions, including Fourier series. 18.075 and 18.04 may not both be taken for credit.
Term 1: *N. P. Warner, A. M. Stuart*
Term 2: *H. Cheng*

18.076 Advanced Calculus for Engineers (A except II, VI, XVI, XVIII, XXII)

Prereq.: 18.075
G (1, 2, S)
3-0-9

Vector analysis: orthogonal curvilinear coordinates. Calculus of variations. Solution of classical partial differential equations of mathematical physics, including applications of conformal mapping and the Laplace transformation. Information: D. S. Jerison.

18.085 Mathematical Methods for Engineers I (A)

Prereq.: 18.03
G (1, 2, S)
3-0-9

Review of linear algebra, applications to networks, structures, and estimation, Lagrange multipliers, differential equations of equilibrium, Laplace's equation and potential flow, boundary-value problems, minimum principles and calculus of variations, Fourier series, discrete Fourier transform, convolution, applications.
Term 1: *G. Strang, Y. Karpishpan*
Term 2: *Staff*

18.086 Mathematical Methods for Engineers II (A)

Prereq.: 18.03
G (1, 2, S)
3-0-9

Scientific computing: Fast Fourier Transform, finite differences, finite elements, spectral method, numerical linear algebra. Complex variables and applications. Initial-value problems: stability or chaos in ordinary differential equations, wave equation vs heat equation, conservation laws and shocks, dissipation and dispersion. Optimization: network flows, linear programming, simplex vs Karmarkar.
Term 1: *A. M. Stuart*
Term 2: *A. Nadim*

18.089 Review of Mathematics

Prereq.: —
G (S)
Arr.

Reviews calculus and differential equations. Primarily for students in Course XIII-A. Degree credit allowed only in special circumstances.
D. S. Jerison

18.093 Tutoring in Mathematics

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1, 2) [P/F]
Arr.

For undergraduates who are teaching mathematics recitation. Limited enrollment, based on positions available. Permission must be secured in advance to register for this subject.
D. S. Jerison

18.097 Writing Mathematics

Prereq.: 18.02, 18.03
U (1, 2)
2-0-4

Seminar on writing mathematics, designed to help math majors satisfy Phase II of the Institute Writing Requirement. For majors with little or no experience in technical writing. Mathematical content geared to sophomore/junior level. A satisfactory final paper can be submitted to fulfill Phase II of the Writing Requirement.
K. M. Hoffman

18.099 Independent Activities

Prereq.: —
U (1, J, 2)
Arr.

For undergraduates desiring credit for studies during IAP or for special individual reading on an undergraduate level during the regular terms. Specific programs and credit arranged in consultation with individual faculty members and subject to departmental approval.
J. R. Munkres

Analysis

18.100 Analysis I (A except XVIII)

Prereq.: 18.03
U (1, 2) G (1, 2)
3-0-9

Two options offered, both covering fundamentals of mathematical analysis: convergence of sequences and series, continuity, differentiability, Riemann integral, sequences and series of functions, uniformity, interchange of limit operations. Both options show the utility of abstract concepts and teach understanding and construction of proofs. *Option A* chooses less abstract definitions and proofs, and gives applications where possible. *Option B* is more abstract and for students with more mathematical maturity. Places greater emphasis on point-set topology.

18.100A Term 1: *B. Chow*
Term 2: *A. Sanchez-Calle*
18.100B Term 1: *D. S. Jerison, Staff*
Term 2: *I. E. Segal, Staff*

18.101 Analysis II (A except XVIII)

Prereq.: 18.100, 18.701 or 18.710
U (1) G (1)
3-0-9

Continues 18.100, stressing the topics most useful in the study of manifolds and global analysis: differentiable maps, Jacobians, differentials, inverse and implicit function theorems, n-dimensional Riemann integral, change of variables in multiple integration, differential forms, general version of Stokes's theorem. 18.901 helpful but not required.
J. R. Munkres

18.103 Fourier Analysis — Theory and Applications (A except XVIII)

Prereq.: 18.100
G (2)
3-0-9

Continues 18.100. Roughly half the subject devoted to the theory of the Lebesgue integral and half to Fourier series and Fourier integrals.
H. F. Smith

18.104 Seminar in Analysis

Prereq.: 18.100
U (1) **Next offered 1989-90**
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics vary from year to year.
A. Sanchez-Calle

18.115 Functions of a Complex Variable (A)

Prereq.: 18.100
G (1)
3-0-9

Exponential and trigonometric functions, Cauchy integral formula, holomorphic and meromorphic functions. Infinite series and products, the gamma function. Harmonic functions, conformal mapping, Dirichlet's problem.
G. Matić

18.116 Topics in Complex Variables (A)

Prereq.: 18.115
G (2) **Next offered 1989-90**
3-0-9

Topics vary from year to year; may be repeated for credit. Typical topics: introduction to Riemann Surface Theory, function-theoretic and geometric approaches to Teichmüller theory. Information: R. B. Melrose

18.117 Topics in Several Complex Variables (A)

Prereq.: 18.115, 18.125
G (1) **Next offered 1989-90**
3-0-9

Cauchy integral formula in polydiscs. Domains of holomorphy, pseudoconvexity, and plurisubharmonic functions. Existence and approximation theorems for holomorphic functions via L^2-estimates for the $\bar{\partial}$-operator. Domains of holomorphy. $\bar{\partial}$-Neumann problem.
Information: R. B. Melrose.

18.125 Lebesgue Integration (A)

Prereq.: 18.100
G (1)
3-0-9

Lebesgue integration, emphasizing applications to harmonic and functional analysis on Euclidean spaces. Hilbert space, Fourier transform, integral operators, elementary differentiation theory, introduction to Sobolev spaces.
D. W. Stroock

18.126 Functional Analysis (A)

Prereq.: 18.125
G (2)
3-0-9

General theory of Hilbert, Banach, and Frechet spaces. Examples, including Sobolev space, L^p, and Schwartz class. The Fourier transform. Boundedness and compactness of operators. Spectral theory for self-adjoint operators. Applications to linear partial differential equations.
D. S. Jerison

18.129 Operator Theory (A)

Prereq.: 18.100B plus one subject in higher analysis
G (2) **Next offered 1989-90**
3-0-9

Linear operators in infinite-dimensional spaces. Spectral theory, self-adjoint operators, one-parameter groups, group representations, analytic vectors. Perturbation and scattering theory; semigroups and generators. Application to problems in mathematical physics, including global theory of nonlinear wave equations. Introduction to operator algebra (C*- and W*-).
I. E. Segal

18.135 Geometric Analysis (A)

Prereq.: 18.125
G (2) **Next offered 1989-90**
3-0-9

Harmonic analysis on R^n. Spherical harmonics. Non-Euclidean Fourier analysis. Paley-Wiener type theorems, group-theoretic potential theory. Eigenfunctions, entire functionals, and hyperfunctions. Radon transforms and applications.
S. Helgason

18.152 Introduction to Differential Equations

Prereq.: 18.100
U (1) **Next offered 1989-90**
3-0-9

Cauchy problem for ordinary differential equations. Integration of vector fields in the plane. The wave equation and Riemann function. Dirichlet problem for Laplace's operator.
R. B. Melrose

18.155 Distributions and Differential Equations (A)

Prereq.: 18.102
G (1)
3-0-9

Treats the basic theory of distributions with many applications to linear ordinary, and partial, differential equations: distributions and elementary operations, Green's formula, wave operators. Fourier transform, temperate distributions, Sobolev spaces, and constant coefficient elliptic operators. Convolution, fundamental solutions, and the Malgrange-Ehrenpreis theorem.
A. Sanchez-Calle

18.156 Introduction to Microlocal Analysis (A)

Prereq.: 18.155, 18.965
G (1)
3-0-9

Examines singularities of distributions. Distributions singular across a submanifold, singular points of ordinary differential equations, noncharacteristic boundary-value problems. Pseudodifferential operators, regularity of elliptic differential operators, wavefront set, and microdistributions. Darboux's theorem. Hamilton-Jacobi theory, the Maslov bundle. Lagrangian distributions, Fourier integral operators, and the Cauchy problem for hyperbolic equations.
R. B. Melrose

18.157 Partial Differential Equations (A)

Prereq.: 18.155, 18.156
G (2) **Next offered 1989-90**
3-0-9

Examines general classes of operators and problems in the theory of linear partial differential operators. Boundary-value problems for elliptic operators, hypoelliptic operators with double characteristics. Operators of real principal type. Uniqueness for the Cauchy problem. Spectral theory.
R. B. Melrose

18.158 Topics in Differential Equations (A)

Prereq.: 18.125
G (2)
3-0-9

Content varies from year to year; may be repeated for credit. Topics: probabilistic methods in elliptic and subelliptic partial differential equations.
D. W. Stroock

18.175 Theory of Probability (A)

Prereq.: 18.125
G (2)
3-0-9

Ergodic theorems, laws of large numbers, convergence of probability measures, central limit theorems, stochastic processes, Brownian motion, martingales, strong Markov properties.
D. W. Stroock

18.177 Stochastic Processes (A)

Prereq.: 18.175
G (1) **Next offered 1989-90**
3-0-9

Topics in stochastic processes, such as Gaussian, Markov, diffusion and empirical processes. Content varies from year to year; may be repeated for credit.
D. W. Stroock

18.199 Graduate Analysis Seminar (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-21

Studies original papers in differential analysis and differential equations. Intended for first- and second-year graduate students. Permission must be secured in advance.
R. B. Melrose

18.238 Geometry and Quantum Field Theory (A)

Prereq.: Permission of Instructor
G (1, 2) **Next offered 1989-90**
3-0-9

Topics vary from year to year; may be repeated for credit.
I. M. Singer

18.257 The Architecture of Fundamental Mathematical Physics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Overview of basic theory from a modern mathematical standpoint. Quantum mechanics and field theory, general concepts of space-time, global theory of nonlinear wave equations and their interrelations. Introduction to gravitation and cosmology.
I. E. Segal

18.276 Mathematical Methods in Physics (A) (New)

Prereq.: —
G (2)
3-0-9

Recent developments in physics require mathematical techniques not usually covered in standard graduate subjects; e.g., Kaehlerian geometry, Kač-Moody algebras, Teichmüller theory, and the theory of Bieberbach groups. Topic for 1988-89: spectral problems associated with periodic lattices in R^n and applications to solid state physics. Topics for following terms: string theory, Yang-Mills and the topology of four manifolds. Content varies from year to year; may be repeated for credit.
V. W. Guillemin

18.284 Introduction to Functions of a Complex Variable (A except XVIII)

Prereq.: 18.03
G (1)
3-0-9

Complex numbers, analytic functions, Riemann surfaces for certain functions, Cauchy's theorem, singularities, residues, contour integrals, conformal mapping. Schwarz-Christoffel transformation, series and sequences, analytic continuation, harmonic functions, conjugate functions, the gamma function. More advanced than 18.04.
H. Cheng

18.295J General Relativity (A)

(Same subject as 8.962J)
Prereq.: 18.06, 8.06, 8.312
G (2)
3-0-9

The physical background and mathematical formulation of the general theory of relativity. Begins with tensor calculus, differential forms, and Riemannian geometry. Ultimately concentrates on the physical properties and global structure of black holes.
N. P. Warner

Applied Mathematics

18.301 Introduction to Physical Mathematics I

Prereq.: 18.03
U (1)
3-0-9

Discussion of mathematical techniques motivated by and applied to scientific problems. Particle mechanics and differential equations. Random walk and the diffusion equation. Asymptotic series and asymptotic estimation of integrals. Fourier analysis. Introduction to Sturm-Liouville problems and special functions. 18.04 or 18.284 helpful.
D. Z. Freedman

18.302 Introduction to Physical Mathematics II

Prereq.: 18.301, 18.04 or 18.284
U (2)
3-0-9

A selection of the following topics are treated. Vector and tensor analysis, variational calculus, formulation and classification of partial differential equations of mathematical physics and continuum mechanics. Solution of the latter equations by separation of variables, Green's function, integral transform methods, and regular and singular perturbation techniques. Knowledge of complex variables desirable but not essential.
D. Z. Freedman

18.305 Methods of Applied Mathematics I (A)

Prereq.: 18.04 or 18.075 or 18.284 or 18.302
G (1)
3-0-9

18.306 Methods of Applied Mathematics II (A)

Prereq.: 18.04 or 18.075 or 18.284 or 18.302
G (2)
3-0-9

A comprehensive treatment of the advanced methods of applied mathematics. Term 1: asymptotic behavior of differential and difference equations; asymptotic evaluation of integrals; regular and singular perturbation methods; boundary-layer techniques; WKB method; multiple scales. Term 2: partial differential equations; transform methods; characteristics, initial and boundary-value problems; Green's functions; singular perturbation problems; nonlinear wave propagation.
18.305: *L. N. Trefethen*
18.306: *C. F. Pearson*

18.307 Methods of Applied Mathematics III (A)

Prereq.: 18.04 or 18.075 or 18.284 or 18.302
G (1)
3-0-9

Selection of material from the following topics: calculus of variations (the first variation and the second variation); integral equations (Volterra equations; Fredholm equations, the Hilbert-Schmidt theorem); the Hilbert Problem and singular integral equations of Cauchy type; Wiener-Hopf Method and partial differential equations; Wiener-Hopf Method and integral equations; group theory.
A. Nadim

18.308 Wave Motion (A)

Prereq.: 18.305
G (1)
3-0-9

Geometrical optics, linear and weakly nonlinear. The particle-wave duality. Geometrical shock dynamics. Modulation theory; formal point of view, the average Lagrangian, wave action and average conservation laws. Multiple phases, small divisors problem, resonant interactions, integro-differential equations. Dynamic homogenization, low-high frequency interactions. Inverse Scattering Transform, solitons, small dispersion limit. Several topics from the modern theory of waves are considered. May be repeated for credit.
R. R. Rosales

18.310 Principles of Applied Mathematics

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1)
3-0-9

Introductory survey of fundamental concepts in applied mathematics: optimization, random process, coding, computer algorithms. This independent half of the complete sequence emphasizes the ideas and topics that relate to a "discrete" mathematical approach: computation, combinatorics, probability, linear programming.
D. J. Kleitman

18.311 Principles of Applied Mathematics

Prereq.: 18.03
U (2)
3-0-9

Introductory survey of fundamental concepts in applied mathematics: propagation, stability, equilibrium, optimization. This independent half of the complete sequence emphasizes the ideas and topics that relate to a "continuous" mathematical approach: diffusion, waves, instabilities, characteristics, and first-order partial differential equations, with applications to traffic problems, fluid flow, and other problems in classical mathematical physics.
A. Nadim

18.313 Probability

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (2) SD **Next offered 1989-90**
4-0-8

Development of theory and applications of probabilistic concepts for scientists and engineers. Emphasizes formulation and solution of probabilistic problems by the algebra of random variables. Topics: sample space, Bernoulli and Poisson processes, uniform process, generating functions and Laplace transforms, discrete and continuous-parameter Markov chains. Introduces the Central Limit Theorem and the foundations of probability. 18.313 and 18.440 may not both be taken for credit.
G-C. Rota

18.314 Applied Combinatorial Analysis

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1)
3-0-9

Combinatorial problems and methods for their solution. Emphasizes problems of enumeration, generating function techniques, and construction of bijections. Additional topics drawn from graph theory, matchings and network flows, partial orders, permutation groups and Polya theory.
E. Schulte

18.315 Combinatorial Theory (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Content varies from year to year; may be repeated for credit. Topics in the past have included enumeration, generating functions, partially ordered sets, Möbius functions, incidence geometries matroids, matching theory, Ramsey theory, graphs.
R. P. Stanley

18.316 Seminar in Combinatorics (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Content varies from year to year; may be repeated for credit. Readings from current research papers in combinatorics. Topic to be chosen and presented by the class.
D. J. Kleitman

18.318 Topics in Combinatorics (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Content varies from year to year; may be repeated for credit. Topic 1988-89: Combinatorics of partial orders and lattices. Incidence algebras, the Steenrod algebra, combinatorial geometries, homology of posets.
M. D. Haiman

18.325 Topics in Applied Mathematics (A)

Prereq.: Permission of Instructor
G (1, 2) **Next offered 1989-90**
3-0-9

Term 1: Fluid dynamics of particulate systems. Underlying themes from continuum mechanics, low Reynolds number hydrodynamics, and transport phenomena. Topics include suspension rheology, sedimentation processes, Brownian motion theory, macromolecular hydrodynamics and viscoelasticity, multiphase flow, and flow in porous media. Term 2: Topics in viscous, incompressible flow. Emphasizes current research in transitional and turbulent flows, primarily of the boundary-layer type. Approach is from the standpoint of stability theory.
Term 1: *A. Nadim*
Term 2: *C. F. Pearson*

18.330 Introduction to Numerical Analysis

Prereq.: 18.03
U (2)
3-0-9

Introduces basic techniques for efficient solution of numerical problems in science and engineering. Root finding, integration, function approximations, differential equations, direct and iterative methods in matrix theory, optimization with constraints, analysis of numerical stability.
A. M. Stuart

18.335 Numerical Methods of Applied Mathematics I (A)

Prereq.: 18.06
G (1)
3-0-9

18.336 Numerical Methods of Applied Mathematics II (A)

Prereq.: 18.302
G (2)
3-0-9

Advanced introduction to theory and application of numerical methods. Term 1: Fundamental methods for various problems including linear equations, quadrature, nonlinear equations, matrix eigenvalues, Fourier transforms, and ordinary differential equations. Term 2: numerical solution of differential equations, especially of time-dependent partial differential equations by finite-difference and spectral methods, together with the associated theory of accuracy, stability, and convergence.
18.335 *A. Toomre*
18.336 *L. N. Trefethen*

18.337 Topics in Numerical Analysis (A) (New)

Prereq.: Permission of Instructor
G (1, 2) **Next offered 1989-90**
3-0-9

Reading and problem solving on a topic in numerical analysis not normally covered by 18.335 or 18.336, to be agreed upon by students and instructor. Possibilities include: optimization and nonlinear equations, approximation theory, sparse matrices, parallel algorithms, boundary-value problems, finite-element methods, numerical methods in complex analysis. Topic varies from term to term; may be repeated for credit.
L. N. Trefethen

18.350 Experiments in Fluid Mechanics (New)

Prereq.: Permission of Instructor
U (2)
3-6-3

A "get your hands wet" approach to fluid mechanics for the theoretically inclined in which students, assisted by laboratory staff, set up and carry out a number of exploratory and diagnostic experiments. These fairly simple demonstrations of basic fluid processes and phenomena are designed to motivate further study by providing the intuition and experience that underlie theoretical models, approximations, and analyses. Enrollment is limited.
H. P. Greenspan

18.354 Fluid Mechanics

Prereq.: 18.04 or 18.075 or 18.302
U (1)
3-0-9

18.355 Fluid Mechanics (A)

Prereq.: 18.354
G (2)
3-0-9

A study of the basic concepts of fluid dynamics: conservation laws of mass, momentum, and energy; equation of state; vorticity and circulation theorems; boundary-layer theory; instability and transition; waves; compressible flows and shocks; convection. Multiphase fluids, and other selected topics of current research interest.
18.354: *H. P. Greenspan*
18.355: *W. V. R. Malkus*

18.356 Rotating Fluids (A)

Prereq.: 18.305, 18.354
G (1) **Next offered 1989-90**
3-0-9

General theory of rotating fluids; transient flows; effects of viscosity, stratification, compressibility and nonlinear interactions; wave motion and stability theory; multiphase flows and centrifugal separation of mixtures. Application to laboratory, technological, and geophysical problems.
H. P. Greenspan

18.357 Seminar in Fluid Dynamics (A)

Prereq.: 18.355
G (1)
3-0-9

Frontiers of nonlinear stability theory. Bifurcation in dynamical systems and the onset of chaos. Poincaré maps. Broadband instability and intermittency in fluids. Applications to geophysics and astrophysics.
W. V. R. Malkus

18.358 Hydrodynamic Stability and Turbulence (A)

Prereq.: 18.354
G (2) **Next offered 1989-90**
3-0-9

Linear stability theory of incompressible and compressible flows. Nonlinear stability theory; modes of transition, the advent of aperiodicity. Upper-bound and statistical theories of turbulence. Statistical stability and the turbulent transport of heat and momentum. Properties of convection and shear turbulence.
W. V. R. Malkus

18.375 Dynamics of Galaxies (A)

Prereq.: 8.06, 18.076, or 18.302
G (2) **Not to be offered 1989-90**
3-0-9

Types and main properties of galaxies. Orbits, equilibria, and instabilities of large aggregates of stars. Wave mechanics in disks: density waves, swing amplification, global modes, resonances, bars; bending waves, forced warps. Evolution of groups: tidal encounters, orbital decay, mergers, refueling the central engines. Effects of dark halos.
A. Toomre

18.395 Group Theory with Applications to Physics (A)

Prereq.: 18.302 or 18.305 or 8.321
G (1) **Next offered 1989-90**
3-0-9

Selection of topics from the theory of finite groups, Lie groups, and group representations, presented with some applications to quantum mechanics and particle physics.
D. Z. Freedman

18.396 Topics in Theoretical Physics (A)

Prereq.: 8.323, *8.324*
G (2) **Next offered 1989-90**
3-0-9

Introduction to supersymmetric quantum field theories and supergravity. Component and superspace formulation of supersymmetric theories. Supersymmetry and renormalization. Two-dimensional supergravity and introduction to superstrings.
D. Z. Freedman

Theoretical Computer Science

18.400J Automata, Computability, and Complexity

(Same subject as 6.045J)
Prereq.: 18.063 or 18.310
U (2)
4-0-8

See description under subject 6.045J.
S. Micali

18.404J Theory of Computation (A except XVIII)

(Same subject as 6.840J)
Prereq.: 18.063 or 18.310
U (1)
4-0-8

A more extensive and theoretical treatment of the material in 6.045J/18.400J, emphasizing computability, computational complexity, and mathematical logic. Reducibility, Kolmogorov complexity. Time and space measures on computation, efficient reducibility, complete problems. Decidable, undecidable, and inherently complex logical theories.
M. Sipser

18.405J Advanced Complexity Theory (A)

(Same subject as 6.841J)
Prereq.: 6.840J/18.404J
G (2)
3-0-9

Current research topics in computational complexity theory. Nondeterministic, alternating, probabilistic, and parallel computation models. Boolean circuits. Complexity classes and complete sets. The polynomial-time hierarchy. Relativization. Definitions of randomness. Approaches to the P = NP? and related questions.
M. Sipser

18.409 Topics in Theoretical Computer Science (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Study of an area of current interest in theoretical computer science. Topic varies from term to term; may be repeated for credit. Topic for Spring 1989: advanced optimization.
É. Tardos

18.410J Introduction to Algorithms

(Same subject as 6.046J)
Prereq.: 6.001, 18.063 or 18.310
U (1, 2)
4-0-8

See description under subject 6.046J.
B. Awerbuch, S. Goldwasser

18.414J Theory of Algorithms (A except XVIII)

(Same subject as 6.851J)
Prereq.: 18.06 or 18.710, 18.063 or 18.310
U (2)
3-0-9

Techniques for design and analysis of algorithms, emphasizing mathematical methods and proofs. Proof-oriented version of 6.046J/18.410J. Topics: Data structures, sorting, selection, hashing. Solving recurrences. Upper and lower bounds. Dynamic programming. Divide and conquer. Graph algorithms: spanning trees, matching, shortest paths, max flow. Matrix operations. Fast Fourier transform. Integer and polynomial arithmetic. Permutation group membership. Primality testing. Linear programming. Parallel algorithms.
R. Rivest

18.415J Advanced Algorithms (A)

(Same subject as 6.854J)
Prereq.: 18.414J/6.851J, 18.06 or 18.710
G (1)
3-0-9

Continuation of 18.414J/6.851J, emphasizing fundamental algorithms and advanced methods of algorithmic design and analysis. Advanced graph algorithms (matching and graph isomorphism). Basis reduction, integer programming, polynomial factorization, diophantine approximation. Linear programming. Probabilistic analysis and methods.
É. Tardos

18.419 Seminar in Theoretical Computer Science (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

A seminar on advanced topics in theoretical computer science. Current literature presented by students and instructors with a view toward preparing students for research in theoretical computer science, and for developing the skills needed to present such results effectively. May be repeated for credit.
D. B. Shmoys

18.421J Algorithmic Algebra and Number Theory

(Same subject as 6.047J)
Prereq.: 18.06 or 18.710, 18. 063 or 18.310 or 18.703
U (2) **Not to be offered 1989-90**
3-0-9

Emphasis on constructing efficient algorithms for classical problems in algebra and number theory. Integer and polynomial GCD computation, modular arithmetic, Chinese remainder theorem, Jacobi symbol computation, primality testing, extracting square roots mod primes, integral lattices, factorization of polynomials over the rationals, simultaneous diophantine approximations, solving binary quadratic and cubic modular equations, application to public-key cryptography.
H. Rogers, Jr., S. Goldwasser

18.423J Computability, Programming, and Logic

(Same subject as 6.044J)
Prereq.: 18.063 or 18.310
U (1)
3-0-9

See description under subject 6.044J.
A. R. Meyer

18.425J Cryptography and Cryptanalysis (A)

(Same subject as 6.875J)
Prereq.: 6.046J/18.410J or 6.851J/18.414J or 6.047J/18.421J
G (2)
3-0-9

See description under subject 6.875J.
S. Goldwasser

18.426J Advanced Topics in Cryptography (A)

(Same subject as 6.876J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 6.876J.
S. Micali

18.427J Program Semantics and Verification (A)

(Same subject as 6.830J)
Prereq.: 6.821, 6.044J/18.423J or 6.045J/18.400J or 6.840J/18.404J
G (2) **Next offered 1989-90**
3-0-9

See description under subject 6.830J.
A. R. Meyer

18.428J Machine Learning (A) (New)

(Same subject as 6.858J)
Prereq.: 6.034, 6.041, or 6.045 (or equivalents)
G (1)
3-0-9

See description under subject 6.858J.
R. L. Rivest

18.431J Graph Algorithms

(Same subject as 6.048J)
Prereq.: 18.310 or 18.314 or 18.063
U (2) **Not to be offered 1989-90**
3-0-9

Emphasizes the design of efficient algorithms for graph theoretic problems. Includes fast algorithms for minimum spanning trees, network flow, multicommodity flow, vertex and edge connectivity, maximum cardinality matchings, planarity testing, and perfect graphs. Alternate years.
D. B. Shmoys

18.433 Combinatorial Optimization and Linear Programming

Prereq.: 18.06 or 18.710, 18.310
U (2) **Next offered 1989-90**
3-0-9

A thorough treatment of linear programming theory, Dantzig's Simplex method, and duality theory. Linear Programming applications to game theory, approximation algorithms, and NP-complete problems. Assignment problem, transportation problem, and min-cost network flow problem. Ellipsoid method and its implications for combinatorial optimization. Integer programming.
D. B. Shmoys

18.435J Theory of Parallel and VLSI Computation (A)

(Same subject as 6.848J)
Prereq.: 6.046J/18.410J or 6.851J/18.414J
G (1)
3-0-9

Introduces parallel computation and very large scale integration. Design and analysis of systolic algorithms for routing, sorting, arithmetic, and graph problems on arrays, trees, hypercubes, and other fixed-connection networks. Network transformations, broadcast simulation, retiming. Mathematical models of hardware. Lower bounds, P-completeness, area-time trade-offs. Layout, placement, routing. 3D models, volume/area universal networks, fat-trees.
F. T. Leighton

18.436J Advanced Parallel and VLSI Computation (A)

(Same subject as 6.849J)
Prereq.: 18.435J/6.848J
G (2) **Not to be offered 1989-90**
3-0-9

Advanced topics in theory of parallel computation and very large scale integration. Algorithms for arithmetic, linear algebra, and graph problems. AKS, columnsort, and universality. Wire routing, compaction, and wafer-scale integration. Fault tolerance and testing. Advanced retiming. Current research topics. Alternate years.
F. T. Leighton, C. E. Leiserson

18.437J Distributed Algorithms (A)

(Same subject as 6.852J)
Prereq.: —
G (1) **Not to be offered 1989-90**
3-0-9

See description under subject 6.852J.
N. Lynch

18.438 Distributed Network Protocols and Graph Algorithms

Prereq.: 18.410J/6.046J
G (2)
3-0-9

Design and analysis of efficient distributed algorithms in communication networks, with emphasis on graph algorithms methods. Models of communication networks: static, dynamic, synchronous, asynchronous. Complexity measures and trade-offs between them. Efficient simulations of stronger models by weaker models. Local management of a global resource. Protocols in dynamic networks: end-to-end, broadcast. Graph algorithms: BFS, MST, max-flow, maximal independent set, coloring. Resolution of deadlocks.
B. Awerbuch

Applied Mathematics: Statistics

18.440 Probability and Random Variables

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1, 2) SD
4-0-8

Topics in applications. Probability spaces, random variables, distribution functions, expected value. Binomial, geometric, hypergeometric, Poisson distributions. Uniform, exponential, normal, gamma and beta distributions. Mean, variance, moments, and generating functions. Conditional probability, Bayes theorem, joint distributions, and distributions of transformed random variables. Tchebychev inequality, law of large numbers, and central limit theorem. Multivariate normal distribution, covariances and correlation. Applications to statistics and decision theory. 18.440 and 18.313 may not both be taken for credit.
Term 1: *R. M. Dudley*
Term 2: *P. J. Huber*

18.441 Statistical Inference (A except XVIII)

Prereq.: 6.041 or 18.440 or 18.313
U (2), G (2)
3-0-9

Introduces statistical inference. Decision theory, hypothesis testing, point and interval estimation. Bayesian methods, maximum-likelihood and likelihood-ratio tests. Chi-square goodness of fit tests. Comparison of populations by parametric and nonparametric methods. Analysis of variance, regression, and correlation. Sequential analysis if time permits. Treatment more mathematical than that of 18.05 and more detailed in its treatment of statistics. Information: R. M. Dudley.

18.443 Statistics for Applications (A except XVIII)

Prereq.: 18.440 or 18.313 or 6.041
G (1)
3-0-9

A broad treatment of statistics, concentrating on specific statistical techniques used in science and industry. Topics: hypothesis testing and estimation. Chi-square goodness of fit, regression, correlation, time-series analysis, analysis of variance and experimental design. Treatment more oriented toward application and less toward theory than 18.441.
G. M. Ljung

18.445J Introduction to Stochastic Processes (A)

(Same subject as 15.073J)
Prereq.: 18.313 or 18.440 or 6.041
G (1, 2)
3-0-9

Introduces the theory and application of stochastic processes. Empirical phenomena for which stochastic processes provide models. Random walk, gambler's ruin, recurrent events, discrete-time Markov chains, Branching processes, Poisson processes, renewal theory. Continuous-time Markov chains, birth and death processes, queueing theory, and Brownian motion.
Term 1: *M. Fygenson*
Term 2: *G. M. Ljung*

18.446 Applied Time-Series Analysis (A)

Prereq.: 18.441 or 18.443 or 15.075
G (2)
3-0-9

Statistical techniques commonly used to analyze time-series data. Topics: estimation of trends and seasonal adjustment, stationary series — autocorrelation and spectrum. Estimation and interpretation of spectra. ARIMA models and fitting them to data. Analysis of bivariate series — cross correlation and cross spectrum. Emphasizes learning techniques by using them on actual data.
G. M. Ljung

18.448 The Analysis of Categorical Data (A)

Prereq.: 18.441 or 18.443 or 15.075
G (1)
3-0-9

Theory and application of log-linear models to multiway contingency tables and other data sets where the dependent variable is categorical. Topics: the Poisson distribution, one-way, two-way, and multiway frequency tables, logit regression, and maximum-likelihood estimation and computations. Class uses and compares various computer programs for the estimation of log-linear models. Most of the technical theoretical material is reserved until the final few weeks of the semester, and students outside of Course XVIII may arrange to substitute a data analysis project for it.
M. Fygenson

18.454 Sampling, Simulation, and Monte Carlo (A)

Prereq.: 18.440 or 18.313 or 6.041
G (1)
3-0-9

Introduction to principles and techniques of sampling for the purpose of a survey. Includes simple random sampling, stratified sampling, systematic sampling, and cluster sampling. Discussion of statistical background of Monte Carlo methods and simulation — prominent parts of experimental mathematics with wide applicability. Includes variance reduction, conditional Monte Carlo, control variates, antithetic variates, regression methods, Monte Carlo optimization, application to statistical inference problems.
P. J. Huber

18.455 Analysis of Variance and Design of Experiments (A)

Prereq.: 18.06, 18.441 or 18.443 or 15.075
G (1) **Next offered 1989-90**
3-0-9

Detailed presentation and use of the classical models of analyses of variance (ANOVA): one-way classification, two-way classifications, block designs, nested designs, latin squares. Model II type designs. Tests of hypothesis, simultaneous confidence intervals. Presentation of regression, and analysis of covariance (ANOCOVA). Properties of the multivariate normal and related distributions, linear models, general linear hypothesis. Geometric interpretation. Finally, effect of departure from assumptions and nonparametric analogs of ANOVA. Information: R. M. Dudley.

18.456 Multivariate Methods in Statistics (A)

Prereq.: 18.06, 18.441 or 18.443 or 15.075
G (2)
3-0-9

Theory and application of commonly used techniques involving multivariate data. Attention devoted to specific applications, and to computational facilities for applying the methods. Selects topics from the following: multivariate regression, discriminant analysis, and pattern classification. Cluster analysis, factor analysis, and principal components. Multidimensional scale analysis. Contingency tables. Information: R. E. Welsch

18.457J Statistical Modeling and Data Analysis (A)

(Same subject as 15.076J)
Prereq.: 18.06, 18.443 or 15.075
G (2) **Next offered 1989-90**
3-0-9

See description under subject 15.076J.
R. E. Welsch

18.458 Robust Statistics and Nonparametric Methods (A)

Prereq.: 18.440, 18.441 or 18.443 or 15.075
G (2)
3-0-9

Overview of robust statistical theory, including asymptotic minimax, infinitesimal (bounded-influence) aspects, robust covariances, and robust regression. Nonparametric methods that give useful and valid results under a very wide class of underlying distributions — particularly useful for social scientists and biologists. Topics: Wilcoxon test, sign test, Wilcoxon-Mann-Whitney test, U-statistics theorems, optimal linear rank tests, Kruskal-Wallis test, rerandomization tests.
P. J. Huber

18.465 Topics in Statistics (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Introduces some special theoretical topics in mathematical statistics at an intermediate level. Assumes familiarity with the elements of probability theory and the fundamental concepts and basic techniques of statistical inference. Topics chosen in accordance with the interests of the instructor and the students. Information: R. M. Dudley.

18.466 Mathematical Statistics (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Decision theory, estimation, confidence intervals, hypothesis testing. Introduces large sample theory. Asymptotic efficiency of alternative statistical procedures. Sequential analysis, empirical Bayes methods. Information: R. M. Dudley.

For additional related subjects in Statistics, see:

Civil Engineering: 1.03, 1.06, 1.15, 1.151, 1.152, 1.202J, 1.205, and 1.732

Electrical Engineering and Computer Science: 6.041, 6.231, 6.262, 6.264, 6.431, 6.432, and 6.435

Economics: 14.30, 14.31, 14.381, 14.382, 14.383, 14.384, 14.385, 14.386, 14.388

Management: 15.034, 15.061, 15.065, 15.074, 15.075, 15.076J, 15.077, 15.306, 15.572, and 15.832

Mathematics: 18.05, 18.175, 18.177, and 18.313

See also: 2.061, 2.845, 5.72, 7.011, 8.044, 8.08, 10.816, 11.220, 11.222, 16.321, 16.37, 16.371, 17.842, 17.846, 17.850, 22.38, 22.40J, and HST 191

Logic

18.504 Seminar in Logic

Prereq.: —
U (2)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter taken from current journals or books. Topics vary from year to year.
M. C. Laskowski

18.510 Introduction to Mathematical Logic and Set Theory (New)

Prereq.: —
U (1) **Not to be offered 1989-90**
3-0-9

Propositional and predicate logic. Elementary model theory: completeness, compactness, and Lowenheim-Skolem theorems. Zermelo-Fraenkel set theory. Ordinals and cardinals. Axiom of choice and transfinite induction. Constructible sets. This subject introduces logic and set theory as a foundation for mathematics, and is especially recommended to students enrolled in theoretical mathematics subjects. 18.510 and 18.511 are offered in alternate years; they may not both be taken for credit.
S. D. Friedman

18.511 Introduction to Mathematical Logic and Recursion Theory

Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

Propositional and predicate logic. Elementary model theory: completeness, compactness, and Lowenheim-Skolem theorems. Elementary recursion theory: enumeration and recursion theorems. Post's Problem. Gödel incompleteness theorem. 18.511 and 18.510 are offered in alternate years; they may not both be taken for credit.
S. D. Friedman

18.515 Mathematical Logic (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

18.516 Mathematical Logic (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

First-order logic. Compactness and ultraproducts. Lowenheim-Skolem theorems and category quantifier elimination. Recursively enumerable sets and definability in arithmetic. Incompleteness and undecidability. Consistency and cut-elimination. Zermelo-Fraenkel set theory. Reflection principles and absoluteness. The constructible universe. Forcing.
18.515: *M. C. Laskowski*
18.516: *E. Hrushovski*

18.535 Graduate Logic Seminar (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Students report on fundamental papers in mathematical logic. Open to all graduate students, not only prospective logicians.
S. D. Friedman

18.565 Recursion Theory (A)

Prereq.: 18.516
G (2) **Next offered 1989-90**
3-0-9

Topics in recursion theory chosen from priority arguments, hyperarithmetic theory, ordinal recursion, E-recursion, theory of projective sets. Permission of instructor required for those not having 18.516. Information: S. D. Friedman.

18.575 Model Theory (A)

Prereq.: 18.516
G (1)
3-0-9

Topics in model theory chosen from stability theory, D-minimal structures, model-theoretic algebra, models of arithmetic. Permission of instructor required for those not having 18.516.
M. C. Laskowski

18.585 Set Theory (A)

Prereq.: 18.516
G (2)
3-0-9

Forcing. Other topics in set theory chosen from large cardinals, combinatorial set theory, iterated forcing, descriptive set theory, fine structure of L. Permission of instructor required for those not having 18.516.
S. D. Friedman

18.595 Seminar on Current Topics in Logic (A)

Prereq.: 18.516
G (1, 2)
3-0-9

Analysis of results of current interest in logic. Students present recent developments in the field for general discussion. Uses formal and informal sources. Topics vary from year to year; may be repeated for credit.
S. D. Friedman

18.597 Universal Algebra (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Topics vary from year to year; may be repeated for credit. Properties shared by algebraic structures, introduction to category theory and lattice theory, elementary equivalence of algebraic structures, properties preserved under algebraic constructions, equational logic, word problems. Information: M. Haiman

Algebra and Number Theory

18.701 Algebra I

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1)
3-0-9

18.702 Algebra II

Prereq.: 18.701
U (2)
3-0-9

More extensive and theoretical than the 18.710-18.703 sequence. Experience with linear equations and matrices helpful. First term: group theory, geometry, and linear algebra. Second term: rings and fields — ideals, polynomial rings, factorization, modules, Jordan form for matrices, extension fields, Galois theory.
M. Artin

18.703 Modern Algebra

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (2) SD
3-0-9

A one-term treatment, covering the traditional algebra topics that have found greatest application in science and engineering as well as in other mathematical disciplines: group theory, emphasizing finite groups; ring theory, including ideals, unique factorization in polynomial and Euclidean rings; field theory, including properties and applications of finite fields. 18.710 and 18.703 together cover most of basic algebra. 18.06 or 18.710 should precede 18.703 if both subjects are to be taken.
R. P. Stanley

18.704 Seminar in Algebra and Number Theory

Prereq.: 18.702 or 18.703
U (1)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics may vary from year to year. Topic for 1988-89: algebraic curves.
S. Kleiman

18.705 Commutative Algebra (A)

Prereq.: 18.701-18.702 or 18.710-18.703
G (1)
3-0-9

Basic topics in commutative algebra, with a brief introduction to categorical ideas and homological algebra. Modules, localization, noetherian rings, finiteness properties, dimension theory.
R. P. Stanley

18.706 Noncommutative Algebra (A)

Prereq.: 18.705
G (2)
3-0-9

Topics in noncommutative algebra, selected from such areas as ring theory, representations of groups and rings, polynomial identity rings. *D. J. Anick*

18.710 Abstract Linear Algebra

Prereq.: 18.02 or 18.021 or 18.022 or 18.023
U (1) SD
3-0-9

An algebraic treatment of linear algebra, including vector spaces, systems of linear equations, bases, linear independence, matrices, determinants, eigenvalues, inner products, quadratic forms, and canonical forms of matrices. Compared with 18.06, more emphasis on theory and proofs, less on matrix calculations and applications.
J. Rathmann

18.711 Game Theory

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

Two-person combinatorial games. Finding winning moves in such games as Nim, Hackenbush, and Dots-and-Boxes. Analysis of positions. Algorithmic and algebraic strategies for reduction of positions. Study of impartial games. Matrix games, continuous games, Arrow's Theorem. No formal prerequisite, but students should be familiar with elements of linear algebra.
N. C. Ankeny

18.715 Topics in Homological Algebra (A)

Prereq.: 18.705
G (2) **Next offered 1989-90**
3-0-9

Content varies from year to year; may be repeated for credit. Topics selected from such areas as cohomology of groups and Lie algebras, K-theory, characteristic classes, higher algebraic K-theory, cyclic cohomology.
H. R. Miller

18.725 Algebraic Geometry (A)

Prereq.: 18.705
G (1)
3-0-9

Introduces algebraic geometry. Centered around the basic techniques of the subject, including the theory of schemes, sheaf cohomology, and the Riemann-Roch theorem for curves.
S. Kleiman

18.727 Topics in Algebraic Geometry (A)

Prereq.: 18.725
G (1, 2)
3-0-9

Topics vary from year to year; may be repeated for credit. Topic for term 1: Space curves: Castelnuovo's bound, Castelnuovo's bound on k-normality, Hilbert schemes, irreducibility of the Hilbert scheme in some range. Topic for term 2: Hodge theory. Topology of complex manifolds, Kahler geometry, Hodge's theorem. Consequences for projective algebraic manifolds. Applications to deformations and moduli: Torelli theorems. Deligne's mixed Hodge theory, connections with arithmetic and other applications.
Term 1: *J. Rathmann*
Term 2: *Y. Karpishpan*

18.728 K-Theory of Algebraic Varieties (A) (New)

Prereq.: 18.725
G (2) **Next offered 1989-90**
3-0-9

Higher algebraic K-theory, higher Chow groups, motivic cohomology.
R. D. MacPherson

18.735 Topics in Algebra (A)

Prereq.: 18.702 or 18.703
G (1, 2)
3-0-9

Topics vary from year to year; may be repeated for credit. Topic for 1988-89: Introduction to Coxeter groups, groups with a BN pair, and Hecke algebras.
Term 1: *M. J. Dyer*
Term 2: *G. Lusztig*

18.737 Linear Algebraic Groups (A)

Prereq.: 18.705
G (1) **Next offered 1989-90**
3-0-9

Introduces the classification of affine groups over an algebraically closed field via their representations as groups of invertible matrices. Information: D. A. Vogan.

18.745 Introduction to Lie Algebras (A)

Prereq.: 18.701 or 18.703
G (1)
3-0-9

Emphasizes theory of Lie algebras and algebraic aspects of Lie theory. Structure of finite-dimensional Lie algebras; Engel and Lie theorems, Cartan subalgebras, Cartan criteria. Structure and classification of semi-simple Lie algebras. Weyl and Levi theorems. Finite-dimensional representations of semi-simple Lie algebras, Weyl character formula. Verma modules.
V. Kač

18.747 Infinite-dimensional Lie Algebras (A)

Prereq.: 18.745
G (2)
3-0-9

Highest-weight representations of infinite-dimensional Lie algebras. Character formulas and combinatorics. Connections to the theory of theta functions and modular forms. Infinite wedge representation and algebraic curves. Vertex representations and their relation to soliton equations and to the quantum field theory. Virasoro algebra and the determinantal formula. Connection to critical exponents in statistical mechanics. Other topics.
V. Kač

18.755 Introduction to Lie Groups (A)

Prereq.: 18.100, 18.710
G (1)
3-0-9

A general introduction to Lie groups. The role of Lie groups in mathematics and physics. Correspondence with Lie algebras. Homogeneous spaces. Adjoint representation. Invariant differential forms and cohomology. Compact Lie groups. Structure of Lie algebras.
S. Helgason

18.756 Analysis on Lie Groups (A)

Prereq.: 18.755
G (2)
3-0-9

Semi-simple Lie groups and symmetric spaces. Topics in function theory on symmetric spaces, such as Fourier analysis and Radon transform, invariant differential operators and potential theory. Emphasizes connections with classical analysis and representation theory.
S. Helgason

18.757 Representations of Lie Groups (A)

Prereq.: 18.755
G (2) **Next offered 1989-90**
3-0-9

An introduction to the representation theory of compact Lie groups. Information: D. A. Vogan.

18.758 Representations of Lie Groups (A)

Prereq.: 18.757
G (1)
3-0-9

Introduction to unitary representations of semi-simple Lie groups: compact groups and the Borel-Weil theorem; parabolic induction; Zuckerman construction; unipotent representations.
B. Kostant

18.769 Topics in Lie Theory (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Topics vary from year to year; may be repeated for credit. Topic for Term 1: Poincaré series and Kloosterman sums. Topic for Term 2: representation theory and D-modules.
J.-S. Li

18.775 Algebraic Number Theory (A)

Prereq.: 18.705
G (1)
3-0-9

18.776 Algebraic Number Theory (A)

Prereq.: 18.775
G (2)
3-0-9

Term 1: Basic algebraic number theory. Algebraic number fields. Ideals, class numbers, units, p-adic numbers. Zeta functions, abelian L-series, and reciprocity laws. Introduction to class field theory. Term 2: Cyclotomic fields. Review of basic theory. L-functions, Bernoulli numbers, and class numbers. Constructions of p-adic L-functions. Gauss and Jacobi sums and distributions. Iwasawa theory. Connections with algebraic geometry via modular curves and Fermat curves.
18.775 *N. C. Ankeny*
18.776 *D. L. Ulmer*

18.781 Theory of Numbers

Prereq.: 18.701 or 18.703
U (2)
3-0-9

Primes, congruences, and arithmetic functions and proofs of their asymptotic formulae. Approximations of the real numbers by rationals, Kronecker's theorem, and the introduction of geometry of numbers. Quadratic forms and quadratic number fields.
Information: R. B. Melrose.

18.785 Analytic Number Theory (A)

Prereq.: 18.115
G (1) **Next offered 1989-90**
3-0-9

Theory of modular forms. Correspondence with Dirichlet series and Hecke operators. The Peterson inner product and the Rankin Selberg method. The analytic aspects of a recent paper of Gross and Zagier.
H. M. Stark

18.786 Topics in Number Theory (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Topics vary from year to year; may be repeated for credit. Topic for 1988-89: Elliptic curves and complex multiplication. Elliptic curves, the addition theorem, discriminants and conductors. Complex multiplication and the reciprocity law. Algebraic aspects of recent work of Gross and Zagier.
H. M. Stark

Topology and Geometry

18.901 Introduction to Topology I (A except XVIII)

Prereq.: 18.100
G (1, 2)
3-0-9

18.902 Introduction to Topology II (A except XVIII)

Prereq.: 18.901, 18.701 or 18.703
G (2) **Next offered 1989-90**
3-0-9

Introduces topology, covering topics fundamental to modern analysis and geometry. Intended for those going on to graduate work. 18.901: topological spaces, connectedness, compactness, continuous functions, separation axioms, function spaces. Metrization theorems, the Tychonoff theorem. Topological groups. 18.902: introduction to algebraic topology. Fundamental group, covering spaces, Van Kampen theorem, classification of covering spaces. Applications to knot theory, classification of compact surfaces, separation theorems in the plane.
18.901: Term 1: *H. R. Miller*
18.901: Term 2: *D. J. Anick*

18.904 Seminar in Topology

Prereq.: 18.901
U (2)
3-0-9

Seminar for mathmatics majors. Students present and discuss the subject matter, taken from current journals or books. Topics may vary from year to year. Covers the same material as 18.902, but in seminar form.
F. P. Peterson

18.905 Algebraic Topology (A)

Prereq.: 18.702 or 18.705; 18.901
G (1)
3-0-9

18.906 Algebraic Topology (A)

Prereq.: 18.905
G (2)
3-0-9

Fundamental group, covering spaces, simplicial homology, simplicial approximation manifolds. Homology and cohomology of topological spaces, universal coefficient theorem, plus additional topics to be chosen by the instructor.
F. P. Peterson

18.915 Graduate Topology Seminar (A)

Prereq.: 18.906
G (1)
3-0-21

Study and discussion of important original papers in the various parts of algebraic and differential topology. Open to all students who have had 18.906 or the equivalent, not only prospective topologists.
D. M. Kan

18.917 Advanced Topology (A)

Prereq.: 18.906
G (2)
3-0-9

Content varying from term to term, so that graduate students taking the subject in successive terms may have an introduction to several important phases of topology such as homotopy theory, cohomology theory, fibre spaces, K-theory, combinatorial topology,and/or differential topology. Homotopy theory, cobordism theory.
H. R. Miller

18.945 Geometry and Topology of Singular Spaces (A) (New)

Prereq.: 18.705 or 18.905 or 18.965
G (2) **Not to be offered 1989-90**
3-0-9

Examples of singular spaces: Schubert varieties, toric varieties, compactifications of locally symmetric spaces. Techniques for studying singular spaces: stratifications, intersection homology, D-modules, mixed Hodge theory. Topics vary from year to year; may be repeated for credit.
R. D. MacPherson

18.950 Elementary Differential Geometry

Prereq.: 18.100, 18.901
U (1)
3-0-9

Study of curves and surfaces in R^3 with specific examples. Frenet formulas, fundamental forms, curvature, Gauss's theorem, geodesics, Gauss-Bonnet theorem. *I. M. Singer*

18.961 Elementary Differential Topology

Prereq.: 18.101, 18.901
U (1) **Next offered 1989-90**
3-0-9

Differentiable manifolds in R^n, differentiable mappings; transversality; Sard's theorem; intersection theory; the Euler characteristic of a manifold and the Lefschetz fixed point theorem; integration on manifolds, Stokes's theorem, DeRham cohomology. Information: R. B. Melrose.

18.965 Geometry of Manifolds (A)

Prereq.: 18.101
G (1)
3-0-9

18.966 Geometry of Manifolds (A)

Prereq.: 18.965
G (2)
3-0-9

Differentiable manifolds, vector fields and forms, introduction to Lie groups, the DeRham theorem, Riemannian manifolds. 18.966 continues 18.965. Focuses on symplectic and complex geometry.
18.965: *R. D. MacPherson*
18.966: *B. Chow*

18.969 Topics in Geometry (A)

Prereq.: 18.965
G (1) **Next offered 1989-90**
3-0-9

Content varies from year to year; may be repeated for credit. Typical topics: equivariant cohomology, Atiyah-Singer index theorems, and group representations.
M. F. Vergne

18.994 Seminar in Geometry

Prereq.: —
U (1)
3-0-9

Seminar for mathematics majors. Students present and discuss the subject matter, taken from current journals or books. Topics may vary from year to year. Topics for 1988-89: Transformation groups, space-time, Lorentzian manifolds, and cosmology.
I. E. Segal

18.999 Mathematical Reading

Prereq.: —
G (1, 2, S)
Arr.

Reading of advanced mathematical treatises under supervision of a member of the Department. For graduate students desiring advanced work not provided in regular subjects.
S. Helgason

Course 20

Program in Applied Biological Sciences

Undergraduate Subjects

Undergraduate Research

20.ThU Undergraduate Thesis

Prereq.: —
U (1, 2, S)
Arr.

Program of undergraduate research, leading to the writing of S.B. thesis; to be arranged by the student and an appropriate faculty member.
M. Chow

20.UR Undergraduate Research Opportunities

Prereq.: —
U (1, 2) [P/F]
Arr.

Opportunities available in a wide variety of research programs in mammalian biochemistry and metabolism, biotechnology, toxicology, food science, and biochemical engineering. Problems emphasize direct and active involvement of undergraduates in laboratory research that may be extended over multiple terms.
M. Chow

20.011 Special Projects in Undergraduate Research

Prereq.: —
U (1)
Arr.

20.012 Special Projects in Undergraduate Research

Prereq.: —
U (2)
Arr.

Directed research in the fields of mammalian biochemistry and metabolism, biotechnology, toxicology, food science, and biochemical engineering.
M. Chow

General Undergraduate Subjects

20.006J Chemicals in the Environment: Human Disease

(Same subject as TPP 53J)
Prereq.: —
U (2)
3-0-6

A course designed for those who want to understand the biological and chemical concepts used to protect the public from hazardous environmental chemicals. Begins with review of current assumptions and considers their accuracy. Focuses on needs and means for rational approaches to finding the actual causes of heritable disease and cancer in humans. Class participation emphasized.
W. G. Thilly

20.08J Biotechnology of Mammalian Cells

(Same subject as 10.56J, 7.52J)
Prereq.: 7.03 or 7.05; 5.60 or 10.13
U (2)
4-0-8

See description under subject 7.52J.
A. J. Sinskey, D. I. C. Wang

Graduate Subjects by Area

Toxicology

20.611 General Toxicology (A)

Prereq.: 7.05
G (2) **Not to be offered 1989-90**
4-0-8

Occurrence and mechanisms of action of toxic chemicals of health significance. Characterization of various forms of toxicity of importance in health-risk estimation — acute and chronic effects, genetic effects, teratogenesis, and carcinogenesis. Extrapolation of toxicological data to humans in regulation of environmental chemicals.
G. N. Wogan, J. E. Harris, S. R. Tannenbaum

20.613 Genetic Toxicology (A)

Prereq.: 7.03
G (1)
4-0-8

Modeling of events leading to induction of genetic change. Role of DNA replication, DNA repair, recombination, and other aspects of cell physiology in determining the probability that specific chemical lesions cause alterations in gene structure and chromosomal integrity. Genetic disease as a public health problem.
W. G. Thilly, J. M. Essigmann

20.618 Laboratory Animals: Usage in Biological Experimentation

Prereq.: 7.01
G (2) **Not to be offered 1989-90**
2-1-3

Introduces current concepts of anesthesia, surgery, disease, and experimental manipulation of the research laboratory animal. Emphasizes the selection of proper animal models and techniques used in the experimental protocol. Techniques and skills learned from lectures and audiovisual aids are practiced in laboratory sessions. Alternate years.
J. G. Fox, J. C. Murphy, C. Newcomer

Biotechnology

20.721 Physical and Engineering Properties of Biomaterials (A)

Prereq.: 5.60, 10.13
G (1) **Not to be offered 1989-90**
3-0-6

Emphasizes the theories, principles, concepts, determination, and analysis of rheological properties of solutions, dispersions, suspensions, gels, emulsions, and solids, with supporting discussions on thermal and surface properties. Considers these properties as related to biotechnology and other industrial processes and their effects on quality criteria and process design. Permission of instructor required. Alternate years.
C. K. Rha

20.723 Fabrication and Structure Synthesis of Biomaterials (A)

Prereq.: 20.721
G (1) **Next offered 1989-90**
3-0-6

Fundamentals of biomaterials fabrication and structure synthesis, including solvation, flocculation, emulsions, foams, gels, granular, plexilaminar networks, fibers, and filaments. Emphasizes encapsulation, thermal treatment, extrusion, and spinning technology as applied to biotechnology and food processing. Selection of raw materials, fabrication methods, and processing conditions to obtain desired structural effects. Alternate years.
C. K. Rha

20.801 Biotechnology (A)

Prereq.: 7.03, 7.05
G (1)
3-0-9

Major study areas include basic principles of bioconversion processes, emphasizing metabolic pathways; mass and energy balances; concepts for strain improvement of industrial microorganisms. Additional topics address the current problems in biotechnology, focusing on plant and animal cell technology.
A. J. Sinskey

20.802J Modeling of Biological Systems (A)

(Same subject as 10.57J)
Prereq.: Permission of Instructor
G (2)
2-0-7

See description under subject 10.57J.
G. Stephanopoulos, A. J. Sinskey

Biochemical Engineering

20.811J Biochemical Engineering (A)

(Same as 10.59J)
Prereq.: Permission of Instructor
G (2)
4-0-8

See description under subject 10.59J.
C. L. Cooney, D. I. C. Wang

20.812J Biochemical Engineering Laboratory (A)

(Same as 10.591J)
Prereq.: Permission of Instructor
G (2)
0-5-1

See description under subject 10.591J.
D. I. C. Wang, C. L. Cooney

20.821 Industrial Microbiology (A)

Prereq.: 7.21
G (1)
3-0-4

Selected topics concerned with the use of microorganisms for the production of substances of industrial, medical, or nutritional value, such as amino acids, antibiotics, vitamins, and organic acids, emphasizing metabolic regulation, genetics, and biochemical pathways leading to fermentation products.
A. L. Demain

20.822 Industrial Microbiology Laboratory (A)

Prereq.: 20.821
G (1)
0-6-0

Laboratory exercise of selected topics presented in 20.821.
A. L. Demain

Seminars, Selected Topics, and Research

20.904 Teaching Experience in Applied Biological Sciences (A)

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

For qualified graduate students interested in teaching. Tutorial or classroom teaching under the supervision of a faculty member. Students selected by interview. Total enrollment limited by availability of suitable teaching assignments.
S. R. Tannenbaum

20.921 Selected Topics in Applied Biological Sciences (A)

Prereq.: —
G (1, 2)
Arr.

Detailed discussion of selected topics of current interest. Classwork in various fields not covered by regular subjects.
Staff

20.941 Research Problems (A)

Prereq.: —
G (1)
Arr.

20.942 Research Problems (A)

Prereq.: —
G (2)
Arr.

Directed research in the field of applied biological sciences.
Staff

20.ThP Thesis Proposal (A)

Prereq.: —
G (1, 2)
0-24-0

Thesis proposal research and presentation to the Thesis Committee.
Staff

20.ThG Graduate Thesis (A)

Prereq.: —
G (1, 2)
Arr.

Program of graduate research, leading to the writing of an S.M. or Ph.D. thesis; to be arranged by the student and appropriate MIT faculty member.
S. R. Tannenbaum

Course 21 Humanities

Literature

21.UR Research in Humanities

Prereq.: —
U (1, 2) [P/F]
Arr.

Individual participation in an ongoing research project. For students in the Undergraduate Research Opportunities Program.
Consult P. S. Khoury.

21.TH T Humanities Pre-Thesis Tutorial

Prereq.: As specified for particular field
U (1, 2)
1-0-5

Definition of and early-stage work on thesis project leading to 21.TH Undergraduate Thesis in Humanities. Taken during the first term of the student's two-term commitment to the thesis project. Student works closely with an individual faculty tutor. Required for all students in Courses XXI, XXI-E, and XXI-S for whom the thesis is a degree requirement.
P. S. Khoury

21.TH Undergraduate Thesis in Humanities

Prereq.: 21.TH T
U (1, 2)
Arr.

Completion of work on the senior major thesis under supervision of a faculty tutor. Includes oral presentation of thesis progress early in the term, assembling and revising the final text, and meeting at the close with a committee of faculty evaluators to discuss the successes and limitations of the project. Required for most students in Courses XXI, XXI-E, and XXI-S (see degree requirements in specific fields).
P. S. Khoury

The subjects listed below are arranged in three graduated categories or tiers:
1) Introductory subjects (21.001-21.010), focused on major literary texts grouped in broad historical and generic sequences, all carrying HASS Distribution credit.
2) Intermediate subjects (21.021-21.120), some carrying HASS Distribution credit and some limited to students who have already taken one literature course. Intermediate subjects explore literary forms in greater depth and center on historical periods, literary themes, or genres. Students are encouraged to consult individual instructors about prerequisite requirements.
3) Seminars (21.171-21.177), restricted to students who have taken at least two previous subjects in literature. Enrollment in seminars is strictly limited to a maximum of 12 students.

A *Supplement* to this catalogue, available from the Humanities Department offices, offers more detailed descriptions of all literature subjects and includes specific information about required texts, writing assignments, and examinations.

Introductory Subjects

21.001 Great Books I: Homer to Dante

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Studies a broad range of texts essential to understanding the two great sources of modern conceptions of the world and humanity's place within it: the ancient world of Greece and Rome and the Judeo-Christian world that challenged and absorbed it. Stresses appreciation and analysis of literary, philosophical, and religious texts which came to represent the common cultural possession of our own culture. Readings include Homer, Sophocles, Aristotle, Plato, Thucydides, Virgil, Lucretius, St. Augustine, and Dante.
Term 1: *D. M. Halperin*
Term 2: *A. C. Kibel, H. A. T. O. Reiche*

21.002 Great Books II: Renaissance to Modernity (New)

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Complementary to 21.001. A broad survey of texts — literary, philosophical, and sociological — studied to trace the growth of secular humanism, the loss of a supernatural perspective upon human events, and changing conceptions of individuality and social and communal purpose. Stresses appreciation and analysis of texts that came to represent the common cultural possession of our time. Readings from Machiavelli, Shakespeare, Cervantes, Milton, Descartes, Rousseau, Kant, Jane Austen, Dostoyevsky, and Nietzsche.
Term 1: *D. M. Halperin*
Term 2: *D. M. Halperin*

21.003 Introduction to Fiction

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Introduces prose narrative, both short stories and the novel. Emphasizes literary structure, social and historical context, the relations between fiction and its audience, the shaping force of race and gender. Syllabus varies from section to section but always includes works by Austen, Hawthorne, Tolstoy, Kafka, and Virginia Woolf.
Term 1: *I. Tayler*
Term 2: *A. C. Kibel*

21.004 Major Poets (Revised Content)

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Emphasis on analytic reading of poetry. Focus on nature and development of major poetic forms in Anglo-American literature, with some attention to other national and cultural traditions. Typical syllabus includes Shakespeare, Pope, Coleridge, Wordsworth, Dickinson, Frost, Bishop, and Rich.
Term 1: *J. Hildebidle*
Term 2: *C. G. Wolff*

21.005 Introduction to Drama

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Extensive reading of dramatic masterworks. Emphasizes development from ancient to contemporary theatre of constituent elements of drama (action, character), and the problematic relation of text to performance. Typically includes Sophocles, Shakespeare, Racine, O'Neill, Beckett.
Term 1: *T. C. Theoharis*
Term 2: *W. J. Paul*

21.006 American Literature (Revised Content)

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Studies the national literature and emerging social values of the United States. After grounding our discussion in issues from 17th-century texts, we move through novels, essays, films, and poems from the mid-19th to the mid-20th centuries, focusing on efforts to define an American identity amidst cultural diversity, and on alternate visions of America. Readings in the works of such writers as Emerson, Whitman, Thoreau, Melville, Frederick Douglass, Dickinson, and Wharton.
Term 1: *S. J. Tapscott*
Term 2: *J. Hildebidle*

21.008 The Bible

(21.708)
Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

An introduction to major Biblical texts including Genesis, Exodus, Job, the prophetic and historic books of the Old Testament, and the Gospels and Epistles. Stresses the place of the Bible as foundation text for central religious, ethical, political, and cosmological thinking. Comparative readings in related traditions, ancient, Near Eastern, and Middle Eastern. Investigation of the Bible as influence in later narrative, philosophic, and artistic traditions.
Term 1: *R. Jones*
Term 2: *T. R. Merritt*

21.009 Shakespeare

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Close study of the major comedies, histories, and tragedies in the context of Renaissance thought, Elizabethan theatre, and the political and social setting of Shakespeare's age. Lectures and class discussions each week, supplemented by occasional reading of scenes and attendance at live or filmed performances.
Term 1: *P. S. Donaldson, L. Kampf*
Term 2: *P. S. Donaldson*

21.010 Film and Literature

Prereq.: —
U (1, 2) HASS-D/HUM-D
4-0-8

Close reading and viewing of masterpieces of film studied in contrast with works of oral, dramatic, and prose narrative. Emphasizes the ways in which narrative values are modified by the nature of media. Study of works by Homer, Sophocles, Shakespeare, Cervantes, Conrad; Kurosawa, Ford, Peckinpah, Woody Allen, Coppola, and Welles.
A. Kibel

Intermediate Subjects

Genres and Themes

21.021 Comedy

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Surveys a range of comic texts from different media, the cultures that produced them, and various theories of comedy. Authors and directors studied include Aristophanes, Plautus or Terence, Shakespeare, Molière, Austen, Joseph Heller, Chaplin, and Keaton.
Term 1: *W. J. Paul*
Term 2: *D. Thorburn*

21.022 Tragedy

Prereq.: —
U (2) HUM-D
3-0-9

Reading and discussion of tragic literature, together with an exploration of theories about the tragic vision. Readings from Sophocles; Shakespeare and his contemporaries; Ibsen, O'Neill; Aristotle and other theorists.
T. C. Theoharis

21.030 Popular Narrative: Masterminds

Prereq.: One subject in literature
U (2)
3-0-9

Examines the relationship between popular and high culture and the problem of evaluating texts that tell stories. Treats a range of narrative and dramatic works as well as films, with emphasis on "popular" writing in relation to American culture. May be repeated once for credit, with permission of instructor.
J. Hildebidle

21.031 The Film Experience

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

An introduction to narrative film, emphasizing the unique properties of the movie house and the motion-picture camera, the historical evolution of the film medium, and the intrinsic artistic qualities of individual films. Syllabus includes such directors as Griffith, Chaplin, Renoir, Ford, Hitchcock, De Sica or Antonioni, others.
Term 1: *D. Thorburn, E. Turk*
Term 2: *W. J. Paul*

21.032J American Television: A Cultural History

(Same subject as STS 052J)
Prereq.: One subject in literature
U (2) **Next offered 1989-90**
3-0-9

Television's evolution as a system of story telling and myth making, studied from anthropological, literary, and cinematic perspectives. Centers on prime-time commercial broadcasting but also examines the medium's technological and economic history as well as the theoretical perspectives from which scholars and policymakers have perceived our television system. Much required viewing as well as readings in media theory and cultural interpretation.
D. Thorburn

21.033 Major Film Directors

Prereq.: One subject in literature
U (1)
4-2-6

Close study of films by major directors. Emphasizes cultural contexts and distinctive styles and themes of each director. Syllabus varies from year to year but includes films from different historical periods and, usually, a mix of American and international films by such directors as Chaplin, Lang, Hitchcock, Ford, Hawks, Renoir, Mizoguchi, Fellini. May be repeated for credit by permission of instructor. For 1988-89: Billy Wilder, Preston Sturges, Blake Edwards.
W. J. Paul

21.041J Women in Literature

(Same subject as SP 436J)
Prereq.: One subject in Literature
U (2)
3-0-9

Women in literature and women's literature. We consider not only the representation of women in literary texts but the impact of gender on the construction of texts: how do women inhabit the literary world and how do they "write" it. Emphasis on English and American texts of the 19th and 20th centuries, by writers such as Jewett, Browning, Wharton, Mansfield, Lessing, Marshall, Brooks.
R. Perry

21.044 New World Literature (New)

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Studies in comparative patterns of development in the diverse American traditions of literature, race, gender, and cultural identity. Works by writers in North America (e.g., slave narratives, Whitman, Hawthorne, Faulkner, Black Elk, Hong Kingston, Morrison), Latin America (slave texts, Dario, Neruda, Borges, Cortazon, Puig, Alegria, Allende), Canada (Davies, Atwood), and the Caribbean (Walcott, Naipaul). *S. J. Tapscott*

21.048 Darwin and Design (New)

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

In *Origin of Species,* Darwin provided a model for understanding the existence of objects and systems manifesting evidence of design without positing a designer, of purpose and mechanism without intelligent agency. Texts deal with pre-Darwinian and later treatment of this topic within literature and speculative thought since the 18th century, with some attention to the modern study of "feedback mechanism" in artificial intelligence. Readings in Hume, Voltaire, Malthus, Darwin, Butler, Hardy, H. G. Welles, and Freud.
A. C. Kibel, J. Paradis

Periods of World Literature

21.060 Medieval Literature

Prereq.: One subject in literature
U (1)
3-0-9

Introduces literature of the Middle Ages, concentrating on such central writers and works as St. Augustine, *The Song of Roland, Beowulf,* Dante, Chrètien de Troyes, Chaucer, and the Pearl-Poet. Secondary reading on the social context of medieval literature. Discussion, short papers.
J. Buckley

21.063 Renaissance Literature

Prereq.: One subject in literature
U (2)
3-0-9

In alternate years, readings are organized around specific topics (Magic and the Arts of Government, Renaissance Self-Fashioning, Families and Fortunes) or genres (lyric, epic, drama). Works drawn primarily from the Italian and English Renaissance, and include such figures as Shakespeare, Ariosto, Machiavelli, More, Jonson, Spenser, Bacon, Wyatt, Donne.
P. S. Donaldson

21.070 Eighteenth-Century Literature

Prereq.: —
U (1)
3-0-9

Introduces England's Augustan age through representative authors and literary forms. Emphasizes these cultural issues: commercialization of art, city vs country, rise of the middle class, travel and exploration, romantic love and marriage, growth of capitalism, party politics, gender stereotypes. Background readings, lectures, slide-shows, group discussion. Authors include Addison and Steele, Defoe, Swift, Astell, Pope, Montagu, Richardson, Fielding, Johnson. Information: A. C. Kibel.

21.071 Major English Novels

Prereq.: One subject in literature
U (2)
3-0-9

Study of 6 to 8 major English novels of the 18th, 19th, and 20th centuries, beginning with Bunyan's *Pilgrim's Progress* and including works by such authors as Defoe, Richardson, Fielding, Sterne, Austen, the Brontës, Dickens, Hardy, Lawrence, Joyce, and Doris Lessing. Historical and critical background readings regularly assigned. Discussion, several papers.
I. Tayler

21.075 Irish Literature

Prereq.: —
U (1)
3-0-9

Studies in the literature and history of Ireland, with special attention to periods of significant social readjustment (the Famine, the Great Migration, the Easter Uprising, the Civil War, the Troubles). Emphasis on the political and comic visions of Irish experience. Readings in works by such writers as W. B. Yeats, John Synge, Augusta Gregory, James Joyce, Samuel Beckett, Bernadette Devlin. Topic for 1988-89: Literature and politics of the 20th century.
S. J. Tapscott

21.076 Romantic Poetry

Prereq.: One subject in literature
U (2)
3-0-9

Close readings of the major British Romantic poets (Blake, Wordsworth, Coleridge, Byron, Scott, Burns, Shelley, Keats), with some attention to their literary and historical context. Discussion and several short papers.
I. Tayler

21.078 Major European Novels

Prereq.: —
U (1)
3-0-9

A study of changing narrative forms in the 19th-century European novel. The changing fortunes of the heroic and romantic ideals. The *motif* of the outsider as a means for depicting social reality. Readings in Cervantes, Balzac, Stendhal, Flaubert, Dostoevsky, Tolstoy, Proust.
A. C. Kibel

21.080 Dostoevsky, Tolstoy, Chekhov: Russia and the Modern Age

Prereq.: —
U (1)
3-0-9

Studies of artistic vision in modernizing Russia. Analyses of *Notes from the Underground, The Brothers Karamazov, Anna Karenina, Hadji Murat, Three Sisters,* and shorter works. Discussion, with reference to critical and biographical materials of the relation of artistic works to society, culture, and historical change.
R. E. MacMaster

21.085 Twentieth-Century Fiction

Prereq.: One subject in literature
U (1)
3-0-9

Tradition and innovation in representative fiction of the early modern period. Recurring themes: the role of the artist in the modern period, the representation of psychological and sexual experience, the virtues (and defects) of the aggressively experimental character of so many modern books. Works by such writers as Conrad, Kipling, Isaac Babel, Kafka, James, Lawrence, Mann, Proust, Ford Madox Ford, Joyce, Woolf, Faulkner, and Nabokov.
D. Thorburn

21.086 Twentieth-Century Drama

Prereq.: One subject in literature
U (2)
3-0-9

Reading and discussion of major modern plays (and some films) from Ibsen through Beckett and beyond. Features works by such authors as Shaw, Chekhov, Pirandello, Odets, Ionesco, Brecht, O'Neill, Pinter, Mrozek, Stoppard, Kaufman and Hart, and Mamet.
T. C. Theoharis

21.087 Modernist Poetry

Prereq.: One subject in literature
U (1)
3-0-9

Studies important trends in modern thought and sensibility as reflected in the poetry of the 20th century. Readings center on Yeats, Eliot, Williams, Stevens, and Frost, with some consideration of such later figures as Roethke, Moore, Auden, Berryman, Wilbur, Larkin, Lowell, and Bishop.
J. Hildebidle

21.088 Contemporary Literature

Prereq.: One subject in literature
U (2)
3-0-9

Fiction, drama, poetry, and film, mostly of the 1960s, 1970s, and 1980s. Focus on a wide range of themes, as well as on experiments with literary and theatrical technique. Readings in such figures as Beckett, Heller, Pinter, Weiss, Rich, Lessing, Walter, Solzhenitsyn, O'Neill, Pynchon, Nabokov, Momaday, Bellow. Format: informal lectures, much discussion, several short papers.
S. J. Tapscott

American Literature

See also 21.006 American Literature

21.101 The American Novel

Prereq.: —
U (2) HUM-D
3-0-9

Works by major American novelists, usually beginning with Hawthorne or Melville and concluding with a contemporary novelist. Major emphasis on reading novels as literary texts, but attention as well to historical, intellectual, and political contexts. The syllabus varies from term to term, but many of the following writers are represented: Hawthorne, Melville, Twain, Cather, Wharton, James, Hemingway, Fitzgerald, Faulkner.
C. G. Wolff

21.104 Race and Identity in American Literature

Prereq.: —
U (1)
3-0-9

The quest for identity in the writing of America's racial and ethnic minorities. Emphasis on the writers' problematic relation to the dominant values and traditions of the majority culture. Readings in Douglass, DuBois, Twain, Melville, Ellison, Wright, Malcolm X, Walker, Hurston, others. Discussion, occasional brief lecture. Information: A. C. Kibel.

21.105 American Voices

Prereq.: —
U (1)
3-0-9

Considers a variety of North Americans attempting to define the dream of success. Materials: "high literature," folktales, slave narratives, blues, films, songs, jokes, Indian narratives, oral history. Reading and listening include selections from the works of Benjamin Franklin, Miguel Piñero, Alice Walker, Black Elk, slave and immigrant narratives, Studs Terkel, Maxine Hong Kingston. Restricted to 25 students.
L. Kampf

21.112 American Authors

Prereq.: One subject in literature
U (1)
3-0-9

Examines in detail the works of three or four American authors. Through close readings of poetry, novels, or plays, addresses such issues as literary influence, cultural diversity, the writer's career. Typically, readings include works by such writers as Twain, Melville, Dickinson, Cabell, Chopin, O'Neill, Faulkner, Baldwin, Frost. Format: Lecture-discussion, papers. Information: A. C. Kibel.

21.120 American Themes

Prereq.: One subject in literature
U (2) **Next offered 1989-90**
3-0-9

Examines unifying themes in American culture through a close reading of literary and extra-literary texts. Special attention is paid to social and historical context; emphasis on such issues as literary nationalism, cultural consensus and conflict, and the existence of an American literary style. Topic varies according to instructor.
A. Lang

Seminars

21.171 Literary Interpretation

Prereq.: Two subjects in literature
U (1) **Next offered 1989-90**
3-0-9

Introduces practice and theory of literary criticism. Seminar focuses on topics such as the history of critical methods and techniques, and the continuity of certain subjects in literary history. Limited to 12.
A. C. Kibel

21.172 Studies in Fiction

Prereq.: Two subjects in literature
U (1, 2)
3-0-9

Intensive study of a range of texts by a single author or by a limited group of novelists whose achievements are mutually illuminating. Some attention to narrative theory, and biographical and cultural backgrounds. Term paper based on seminar presentation. Topics for 1988-89: Term 1: The Brontës; Term 2: Conrad, Joyce, and Faulkner. Limited to 12.
Term 1: *I. Tayler*
Term 2: *D. Thorburn*

21.173 Studies in Drama

Prereq.: Two subjects in literature
U (1)
3-0-9

Close study of two or three major dramatists, emphasizing the evolution of their work. Some attention to historical and theoretical accounts of the nature of drama. Topics for 1988-89: Ibsen, O'Neill, Beckett. Limited to 12.
T. C. Theoharis

21.174 Studies in Poetry

Prereq.: Two subjects in literature
U (2)
3-0-9

Extensive reading of works of a few major poets. Emphasizes the evolution of each poet's work and the questions of poetic influence and literary tradition. Topic for 1988-89: Three Poets. Limited to 12.
Information: A. C. Kibel.

21.175J Major Authors

(Same subject as SP 438J)
Prereq.: Two subjects in literature
U (2)
3-0-9

Close study of a limited group of writers. Topic for 1988-89: Jane Austen — Texts and Context. Limited to 12.
R. Perry

21.176 Studies in Film and Media

Prereq.: Two subjects in literature
U (2)
3-0-9

Intensive study of films of a particular period or genre, or films by a single director. Topic for 1988-89: Introduction to Topics in Film Theory. Limited to 12.
M. Geisler, E. Turk

21.177 Problems in Cultural Interpretation

Prereq.: Two subjects in literature
U (2)
3-0-9

Studies in the relation between imaginative texts and the culture surrounding them. Emphasizes ways in which imaginative works absorb, reflect, and conflict with reigning attitudes and world views. Topic for 1988-89: The Construction of Sexuality. Limited to 12.
D. M. Halperin

21.198 Special Topics in Literature

Prereq.: Two subjects in literature
U (1)
Arr.

21.199 Special Topics in Literature

Prereq.: Two subjects in literature
U (2)
Arr.

Open to qualified students who wish to pursue special studies or projects with members of the Literature faculty. Before registering for this subject, students must secure the approval of the Literature faculty chairman. Humanities credit for Special Topics subjects awarded only by individual petitions to the Committee on Curricula. Normal maximum is 6 units; to count toward Humanities Requirement, 9 units are required. Exceptional 9-unit projects occasionally approved.
A. C. Kibel

Foreign Languages and Literatures

The subjects listed below include language and literature courses given in French, German, Greek, Russian, Spanish, and World Literature in Translation. All language subjects in the III-IV sequence bear HASS Distribution credit. A variety of literature subjects given in the original language as well as some given in English also offer HASS Distribution credit.

For guidelines on World Literature in Translation, come to the Foreign Languages and Literatures Office, 14N-207.

All foreign language subjects I-IV are open to graduate students for credit.

For subjects in English as a Foreign Language see 21.326-21.340.

French

The indication of prerequisites for specific French offerings does not apply to students who have already accomplished the equivalent work. For further placement advice, attend the French Placement Session or consult with a field advisor in French.

Fundamental Language Subjects

All fundamental language subjects are conducted in French.

21.201 French I

Prereq.: —
U (1, 2)
4-0-8

Introduction to French language and culture. Emphasis on the acquisition of vocabulary and grammatical concepts through active communication. Immediate exposure to authentic French via video sources and printed material for developing cultural awareness as well as linguistic proficiency. Coordinated language lab program.
G. Furstenberg

21.202 French II

Prereq.: French I
U (1, 2)
4-0-8

Continuation of French I. Further development of linguistic proficiency through active communication. Expansion of vocabulary and completion of the basics of French grammar. Continued exposure to culturally authentic audio and video materials in the classroom and the language lab. Study of French poetry and short literary texts. Increased practice in writing.
G. Furstenberg

21.203 French III

Prereq.: French II
U (1, 2)
4-0-8

Review and expanded study of selected aspects of French grammar and usage. Readings, audiotapes, and discussions on topics in contemporary French civilization and in selected periods of French history. Detailed analysis of a modern play, a short story, three films, and several poems. Weekly practice in composition. Daily exercises in self-expression, communication, and vocabulary.
E. B. Turk

21.204 French IV (Revised Content)

Prereq.: French III
U (1, 2) HASS-D/HUM-D
4-0-8

Final subject in French language sequence. Prepares students for intermediate subjects in French civilization and literature. Organized around the moral, social, and political issues that youth is confronted with in French society. Texts include one play, one novel, one film, and articles from French periodicals. Perfecting of writing and oral skills through frequent essays and class presentations.
J. Brami, I. de Courtivron

Intermediate Subjects in Language, Literature, and Civilization

It is recommended but not required that students take one of the following intermediate-level subjects before enrolling in 21.213 and above. All intermediate and advanced subjects are conducted entirely in French.

21.207 French Conversation: Intensive Practice

Prereq.: French IV
U (1, 2)
4-3-2

Systematic training in oral expression: communication skills, fluency, and idiomatic French. Audio and video tapes to improve conversational techniques and other forms of oral expression (debates, speeches, reports, interviews). Work in comprehension, phonetics, and intonation. Discussion material: newspapers, magazines, cartoons, films, and varied audio and video tapes dealing with issues in contemporary France and the French-speaking world. Intensive lab work. Special projects (video and other) by students. Limited to 16.
G. Furstenberg

21.208 Writing in French: Intensive Practice

Prereq.: French IV
U (2)
3-0-6

Systematic acquisition of writing skills. Emphasizes enrichment of vocabulary, the mastery of complex grammatical structures, the refinement of style, and techniques of composition. Practice in different modes (descriptive, narrative, argumentative) and forms (newspaper articles, advertising, letters, technical and creative writing). Systematic exercises in grammar, vocabulary, and stylistics. Weekly papers, each focusing on a different writing mode and form.
P. Baudoin

21.211 Introduction to French Literature

Prereq.: French IV
U (1) HASS-D/HUM-D
3-0-9

A basic study of major French literary genres — poetry, drama, and fiction — and an introduction to methods of literary analysis. Authors include Racine, Molière, Rousseau, Balzac, Hugo, Flaubert, Baudelaire, Rimbaud, Apollinaire, Duras. Special attention devoted to the improvement of French language skills.
E. B. Turk

21.212 The French Press

Prereq.: French IV
U (2) **Next offered 1989-90**
3-0-6

Explores political and social issues of contemporary interest in French society as expressed in the daily and weekly French press. Readings are extensive and include a variety of newspaper and magazine selections revealing a wide range of public opinion in France. Cultural differences between France and the USA, as reflected in their respective presses, are emphasized. Students are expected to participate actively and to take turns leading the discussions. Polemics are encouraged.
E. B. Turk

Advanced Subjects in Literature and Civilization

All intermediate and advanced subjects are conducted entirely in French.

21.213 French Classical Literature From Descartes to Molière

Prereq.: French IV
U (2) **Not to be offered 1989-90**
3-0-6

Reading and interpretation of masterworks in 17th-century French theater (Corneille, Molière, Racine), poetry (Malherbe, La Fontaine), and philosophy (Pascal, Descartes). Studied in the context of social, historical, and intellectual currents during the eras of Richelieu and Louis XIV, and the evolution from the baroque to the classic aesthetic.
E. B. Turk

21.215 French Culture and Society I: From the Commune to the Popular Front

Prereq.: French IV
U (1) **Not to be offered 1989-90**
3-0-6

Investigates major social, ideological, and aesthetic currents in French civilization from the beginning of the Third Republic to the eve of World War II. Topics studied include history, education, literary and artistic movements, cinema, intellectual and political trends. Texts selected from fiction and non-fiction.
P. Baudoin

21.216 French Culture and Society II: From the Occupation to the Mitterand Years

Prereq.: French IV
U (1) HUM-D **Next offered 1989-90**
3-0-9

Studies intellectual and political currents, literature, and the arts from World War II to the present. Topics include the Occupation and the Resistance, the reconstruction of France, decolonization, May '68; also covered will be post-war intellectual life, existentialism, the new novel, the theater of the absurd, structuralism, and feminism. Special attention is paid to contemporary French society of the 1980s.
I. de Courtivron

21.217 Introduction to French Poetry

Prereq.: French IV
U (1) **Next offered 1989-90**
3-0-6

Development of poetic forms, techniques, and styles. Narrative, descriptive, baroque, polemical, lyric, and pure poetry, poetry of ideas, and the prose poem. Deals with poetry of Villon, Marot, Ronsard, Boileau, La Fontaine, Chénier, Hugo, Nerval, Baudelaire, Rimbaud, Mallarmé, Apollinaire, Valéry, Eluard, Char, Michaux.
R. E. Jones

21.218 Introduction to the French Short Story

Prereq.: French IV
U (1) **Not to be offered 1989-90**
3-0-6

Studies literary movements of the last three centuries through short stories by major French authors. Special attention paid to the theme of the fantastic and the supernatural. Works by Voltaire, Balzac, Mérimée, Maupassant, Colette, and Michel Tournier.
K. Crecelius

21.220 Masterworks of the French Nineteenth-Century Novel

Prereq.: French IV
U (1) **Next offered 1989-90**
3-0-6

The golden age of the French novel. Emphasizes Romanticism, Realism, and Naturalism in Balzac, Stendhal, Sand, Flaubert, and Zola. Themes include the interaction of love, money, and politics in the newly developed bourgeois society of 19th-century France. Devotes attention to narrative techniques, representations of reality, and the influence of history and science.
I. de Courtivron

21.221 French Romanticism

Prereq.: French IV
U (2) **Next offered 1989-90**
3-0-9

Study of French literature and culture from 1800 to 1850, with emphasis on the High Romantic period (1830s). Readings from Musset, Lamartine, Desbordes-Valmore, Chateaubriand, Stael, Balzac, Sand, Hugo. Discussion of the art and music of the era, as well as of the historical and social context of the Romantic movement.
R. E. Jones

21.222 The French Novel in the Twentieth Century

Prereq.: French IV
U (2) **Next offered 1989-90**
3-0-6

Techniques and themes of the modern novel in works by Gide, Proust, Colette, Mauriac, Cocteau, Yourcenar, Camus, and Sarraute. Themes include love, jealousy, adolescence, responsibility to self and to others. Emphasizes the search for identity in an increasingly fragmented and violent world.
J. Brami

21.223 Modern French Drama

Prereq.: French IV
U (2) **Not to be offered 1989-90**
3-0-6

Studies the tragedians Claudel and Montherlant; the poetic fantasy of Giraudoux; the social and philosophical theater of Lenormand, Anouilh, Sartre, Camus; the avant-garde works of Jarry, Apollinaire, Cocteau; plays by Vian, Beckett, Ionesco, and Genet. Special attention to evolving concepts of the director, actor, audience, stage design, and music.
I. de Courtivron

21.228 French Film Classics

Prereq.: French IV
U (2) **Next offered 1989-90**
3-0-6

History and aesthetics of French cinema from the advent of sound to the present day. Treats films in the context of technical processes, the art of narration, directorial style, role of the scriptwriter, the development of schools and movements, the impact of political events and ideologies, and the relation between French and other national cinemas. Directors studied include Clair, Vigo, Feyder, Duvivier, Carné, Renoir, Clouzot, Ophuls, Godard, and Truffaut. Films shown with English subtitles.
E. B. Turk

German

The indication of prerequisites for specific German offerings does not apply to students who have already accomplished the equivalent work. For further placement advice, attend the German Placement Session or consult with a field advisor in German.

Subjects numbered 21.230 to 21.248 may be used to fulfill Institute requirements including concentrating and majoring in German.

Fundamental Language Subjects

21.230 German Review

Prereq.: Permission of Instructor
U (1)
4-0-8

Reviews the grammar of German I and German II. Followed by some of the readings of German II. For students with incomplete previous preparation in German and for those whose study of German is discontinuous. Students may register for German III upon successful completion.
E. Waldstein

21.231 German I

Prereq.: —
U (1, 2)
4-0-8

Basic principles of the German language. Fundamentals of pronunciation, intonation, and grammar. Acquisition of basic vocabulary. Laboratory exercises to further communicative competence.
E. Crocker

21.232 German II

Prereq.: German I
U (1, 2)
4-0-8

Continued practice in pronunciation and intonation. Vocabulary building, review and extension of basic grammar. Practice in writing short essays. Reading of short literary texts. Introduces the history and culture of German-speaking countries.
M. Knittel

21.233 German III

Prereq.: German Review or German II
U (1, 2)
4-0-8

Intensive review of German grammar. Reading of works by such major 20th-century authors as Dürrenmatt, Brecht, Böll, H. Novak, and others. Compositions and discussions based on these works, lab materials, and videotapes on contemporary Germany. Recommended for students with two or more years of high school German.
M. Geisler

21.234 German IV (Revised Content)

Prereq.: German III
U (1, 2) HASS-D/HUM-D
4-0-8

Further deepening of an understanding of German language and culture. Interpretation of literary texts (Grimm, Kafka, Hesse, Brecht), discussion of cultural topics, development of oral communicative competence in practical everyday situations.
C. Kramsch

Intermediate and Advanced Subjects in Language, Literature, and Culture

All intermediate and advanced subjects are conducted entirely in German.

21.237 German Drama Workshop

Prereq.: German III
U (1) **Next offered 1989-90**
3-3-6

Participatory German drama subject. Studies several plays by one author or from one period, of which one is selected for rehearsal and final performance. Intensive pronunciation/intonation practice through instructor-monitored laboratory sessions and small-group rehearsals. No previous acting experience necessary.
M. Geisler

21.238 Advanced German Conversation and Composition

Prereq.: German IV
U (1) **Not to be offered 1989-90**
4-0-8

Systematic training in speaking and writing skills to improve fluency and style. Informal discussions and analyses of tapes by native speakers, newspapers, and modern expository prose. Focuses on everyday life in present-day Germany and on controversial issues, East and West. In addition, students select a special project on a topic of their choice.
C. J. Kramsch

21.239 Introduction to German Literature

Prereq.: German IV
U (1) HASS-D/HUM-D
3-0-9

Readings from German prose fiction, poetry, and drama. Authors include Goethe, Brecht, T. Mann, Keller, Kafka, Rilke, Christa Wolf. Literary language as specialized communication; its conventions and presuppositions; relation of author to audience; imitation of reality vs experimentation with reality; purpose in literature: aesthetic, analytic, parodistic, and political goals. Conducted entirely in German, emphasizing reading, speaking, and writing skills.
E. Waldstein

21.240 German Culture and Society: 1750-1914

Prereq.: German IV
U (2) HUM-D **Not to be offered 1989-90**
3-0-9

German Enlightenment, impact of the French Revolution on Germany, the failure of liberalism, the discrepancy between economic and political development, and the increasing polarization of society as manifested in the various forms of cultural expression. Readings include Lessing, Goethe, Schiller, Hegel, Schopenhauer, Büchner, L. Otto-Peters, Marx, Engels, Nietzsche, Wagner, Bismarck, B. von Suttner, and Freud.
M. Knittel

21.241 Fantasy and Reality in Nineteenth-Century German Literature

Prereq.: German IV
U (2) **Not to be offered 1989-90**
3-0-6

Origin and development of political and cultural movements in the 19th century (Romanticism, Biedermeier, Young Germany, Realism, Naturalism). Impact of these movements on literary style, with emphasis on concepts of fantasy and reality. Genres include traditional forms (drama, novel, short prose, poetry) and nontraditional ones (letters, diaries, reportage, pamphlets). Writers include F. Schlegel, B. v. Arnim, Hölderlin, Kleist, Grillparzer, Heine, Büchner, Keller, Fontane, Storm, Droste-Hülshoff, Hauptmann, and Nietzsche.
M. Geisler, E. Waldstein

21.242 From the Great War to an Uncertain Peace: Twentieth-Century German Literature

Prereq.: German IV
U (1) **Next offered 1989-90**
3-0-6

Literature of the German-speaking countries viewed against the backdrop of history (World War I, inflation and depression, National Socialism, the anti-Nazi resistance and exile, World War II, the division of Germany, the Cold War and détente) and cultural trends (Expressionism, Dadaism, Fascist "culture," anti-fascist humanism, the "new" beginning after 1945 in East and West). Authors include Hesse, Th. and H. Mann, Brecht, Frisch, Grass, Weiss, Böll, and C. Wolf.
M. Geisler

21.243 German Short Fiction

Prereq.: German IV
U (2) **Next offered 1989-90**
3-0-6

Short fiction in the 19th and 20th centuries (Novelle, Erzählung). Representative works read and discussed, emphasizing narrative strategy, esthetic structure, social concern, and historical context. Authors include Kleist, E. T. A. Hoffmann, Büchner, Schnitzler, Döblin, Musil, Grass, and Frisch.
E. Waldstein

21.244 Topics in German Literature

Prereq.: German IV
U (2) **Not to be offered 1989-90**
3-0-6

German literary and cultural history from a thematic perspective. Analyzes the transformations of major themes in German culture from the Middle Ages to the present. Reference to related developments in art, music, film, and media. Emphasis on cultural, social, and political ramifications of topics discussed. Topics vary from one year to the next.
M. Geisler

Greek

Study of the Greek language may be undertaken by special arrangement with the instructor under course 21.348/21.349, *Special Topics in Foreign Languages*. Contact: H. A. T. O Reiche.

Japanese

The indication of prerequisites for specific Japanese offerings does not apply to students who have already accomplished the equivalent work. For further placement advice, consult with a field advisor in Japanese.

Fundamental Language Subjects

21.250 Japanese I (New)

Prereq.: —
U (1)
4-0-8

Introduction to modern standard Japanese. Emphasis on developing proficiency in speaking and listening, using basic grammar and vocabulary. Basic skills in reading and writing are also taught. Lab work required.
T. Graham

21.251 Japanese II (New)

Prereq.: Japanese I
U (2)
4-0-8

Continuation of Japanese I. Further development of the four basic skills. Extension of basic grammar. Vocabulary and *kanji* (Chinese characters) building. Lab work required.
T. Graham

21.252 Japanese III (New)

Prereq.: Japanese II
U (1)
4-0-8

Continuation of Japanese II. Further development of the four basic skills. Completion of basic grammar introduction. Continued vocabulary and *kanji* building. Emphasis on reading and writing. Lab work required.
M. Tsutsui

21.253 Japanese IV (New)

Prereq.: Japanese III
U (2)
4-0-8

Review and expansion of basic grammar. Emphasis on application of basic grammar and vocabulary in various situations. Introduction to society and culture through video and reading. Lab work required.
M. Tsutsui

Russian

The indication of prerequisites for specific Russian offerings does not apply to students who have already accomplished the equivalent work. For further placement advice, attend the Russian Placement Session or consult with a field advisor in Russian.

Fundamental Language Subjects

21.261 Russian I

Prereq.: —
U (1)
4-0-8

Basic grammar and practice in the elements of Russian. Emphasis on learning to speak and understand with practice in reading and writing. Use of videotapes and language laboratory to gain facility in various communicative situations and broaden understanding of Russian culture.
A. Perkins

21.262 Russian II

Prereq.: Russian I
U (2)
4-0-8

Continuation of 21.261. Develops ability to use the language through systematic study of grammar. Continued practice in understanding and speaking with independent reading and creative writing assignments to supplement texts.
A. Perkins

21.263 Russian III

Prereq.: Russian II
U (1)
4-0-8

Reading and discussion of historical texts, stories, and poems providing background for understanding Russian literature and contemporary Soviet culture. Reviews grammar with the help of oral and written exercises. Systematic study of word formation and other strategies to free student from dependency on the dictionary. Develops aural comprehension in the language laboratory. Compositions based on readings and recordings integrate communication skills and help retain content.
E. Semeka

21.264 Russian IV (Revised Content)

Prereq.: Russian III
U (2) HASS-D/HUM-D
4-0-8

Reading of literary and expository texts selected to provide an understanding of Soviet life and culture. Discussion and papers based on readings. Attention to problems of grammar and style, with a view to improving facility in oral and written expression. Aural comprehension developed through brief lectures on cultural topics as well as through taped materials.
C. V. Chvany

Advanced Subjects

21.265 Advanced Russian Conversation and Composition

Prereq.: Russian IV
U (1) **Next offered 1989-90**
4-0-8

Review and systematization of the structure of modern Russian. Intensive training in spoken and written skills to improve fluency and style. Discussions and analyses of short works of fiction and nonfiction illustrating the various styles of spoken and written Russian. Extensive use of taped materials. Conducted in Russian.
C. V. Chvany

21.267 Modes and Styles of Russian Storytelling

Prereq.: Russian IV
U (1) **Not to be offered 1989-90**
3-0-6

Focuses on practical stylistics and vocabulary enrichment through narrative. Illustrates the markers of folkloric, archaic, poetic, bureaucratic, familiar, or formal styles through folktales, newspaper reports, and plot-ridden stories representing a narrative norm. Analyzes famous modern short stories which play with expectations based on that norm. Develops expository style through frequent short papers. Conducted in Russian.
C. V. Chvany

21.268 Topics in Russian and Soviet Culture for Advanced Students

Prereq.: Five terms of Russian
U (1) **Next offered 1989-90**
3-0-6

Introduces problems and controversies of Soviet life and culture. Expository and literary texts provide the necessary background; current issues elucidated through the eyes of contemporary poets, singers, and performers — the so-called "Soviet Bards." Selected songs and contemporary prose deal with matters such as individual vs the state; generation gaps; men, women, and family.
E. Semeka

21.270 Pushkin and His Successors (Revised Content and Unit)

Prereq.: Russian IV or equivalent
U (2)
3-0-6

Acquaints the student with foundations of modern Russian literature through the most important and characteristic works of Pushkin and his successors, mainly Turgenev and Chekhov. Intensive work on composition and stylistics. Conducted in Russian.
C. V. Chvany

21.271 Contemporary Russian Prose and Poetry (Revised Unit)

Prereq.: Russian IV
U (2) **Not to be offered 1989-90**
3-0-6

A study of Russian literature from 1954 up to our time. Besides the writers of the so-called "thaw period" (V. Panova, I. Ehrenburg), such authors as A. Solzhenitsyn, L. Chukovskaya, and poet-singer B. Okudzhava are included. Conducted in Russian.
E. Semeka

Spanish

The indication of prerequisites for specific Spanish offerings does not apply to students who have already accomplished the equivalent work. For further placement advice, attend the Spanish Placement Session or consult with a field advisor in Spanish.

Fundamental Language Subjects

All fundamental language subjects are conducted in Spanish.

21.275 Spanish I

Prereq.: —
U (1, 2)
4-0-8

Introduction to understanding, speaking, reading, and writing Spanish. Maximal use of fundamentals of grammar in active communication. Language laboratory program coordinated with and supplementary to class work.
E. Lilienfeld

21.276 Spanish II

Prereq.: Spanish I
U (1, 2)
4-0-8

Continuation of Spanish I. Increased practice in reading. Conducted in Spanish whenever practical.
D. Barzana

21.277 Spanish III

Prereq.: Spanish II
U (1, 2) HUM-D
4-0-8

Aims at consolidation and expansion of skills in oral comprehension, speaking, reading, and writing. Uses short texts, taped interviews, and movies to study specific social issues of current interest in Hispanic culture.
D. Morgenstern

21.278 Spanish IV (Revised Content)

Prereq.: Spanish III
U (1, 2) HASS-D/HUM-D
4-0-8

Continued study of the language, literature, and culture of Spanish-speaking countries. Materials are from both Spain and Latin America and include feature-length films, a novel by García Márquez, a play by Lorca, a comic book by Quino, and readings on Spanish cultural history.
E. Garrels

21.279 Oral Communication in Spanish

Prereq.: Spanish II
U (2) **Next offered 1989-90**
3-0-6

Gives students the necessary language skills to perform successfully in Spanish in a variety of social situations. Focus on oral communication. Uses popular media for listening practice; other materials include newspapers and magazines. Arranges systematic exchanges with native speakers. Student projects involve reading, oral presentations, and classroom interaction. Emphasizes communication skills needed by students in engineering and management for work in Latin America or Spain.
D. Morgenstern

Intermediate Subjects in Language, Literature, and Culture

It is recommended, but not required, that students take one of the following intermediate level subjects before enrolling in 21.286 and above. All intermediate and advanced subjects are conducted entirely in Spanish with the exception of 21.293.

21.281 Spanish Conversation and Composition

Prereq.: Spanish IV or equivalent
U (1)
3-0-6

Systematic training in spoken and written skills to improve fluency and style. Oral reports by participants on individual topics. Discussions with native speakers, analyses of selected literary texts, periodicals, and local Spanish-language media. Focus is on everyday life in the contemporary Spanish-speaking world.
D. Morgenstern

21.282 Spanish for Bilingual Students

Prereq.: Fluency in a Spanish dialect
U (2) **Not to be offered 1989-90**
3-0-9

Designed for students of Hispanic background brought up in the US. Expands oral and written grammar study and increases contact with standard Spanish; studies recent fiction and poetry as well as specific historical, social, economic, and political aspects of Mexican-American, Puerto Rican, and Cuban cultures. Many of the nonliterary readings are in English; class discussions in Spanish.
D. Morgenstern

21.283 Spanish Drama Workshop

Prereq.: Spanish IV
U (2) **Not to be offered 1989-90**
3-3-6

Participatory Spanish drama subject. Studies several plays by one author or from one period, of which one is selected for rehearsal and final performance. Intensive pronunciation/vocabulary expansion practice through instructor-monitored laboratory sessions and small-group rehearsals. Students work on writing their own one-act plays. No previous acting experience necessary.
E. Garrels

21.284 Introduction to Latin American Culture

Prereq.: Spanish IV
U (2) **Not to be offered 1989-90**
3-0-6

Overview of Latin America's cultural and literary development from the Discovery and Conquest to the present. Addresses through a study of literary texts, film, and art, the questions of racial and cultural heterogeneity in Latin America, the area's psychological relationship to Europe and the US, and particular ways in which the society experiences tradition and social change. Not open to native speakers.
E. Garrels

21.285 Introduction to Spanish Culture

Prereq.: Spanish IV
U (1) HUM-D **Next offered 1989-90**
3-0-9

Studies the major social, political, and aesthetic modes which have shaped Spanish civilization. Coordinates the study of literature and the arts with the historical evolution of Spain. Readings and discussion focus on such topics as: the coexistence of Christians, Moors, and Jews, Imperial Spain, The First and Second Republics, and the contemporary period as background for the emergence of distinctively Spanish literary and artistic movements. Special emphasis on the Spanish Civil War and its aftermath.
M. Resnick

Advanced Subjects in Literature and Culture

21.286 Latin American Literature 1492-1898: Creation of a Continent

Prereq.: Spanish IV
U (1) **Not to be offered 1989-90**
3-0-6

Traces the creation of a new literature to record and interpret a new reality. Begins with the Spanish Discovery and Conquest and studies the unfolding of the secular struggle of Spanish speakers in the Americas to give meaning to their experience through literature. Readings up to the Spanish American War of 1898, including texts by Colón, Bernal Díaz del Castillo, Sor Juana Inés de la Cruz, Esteban Echeverría, Sarmiento, Ricardo Palma, José Martí, and Rubén Darío.
E. Garrels

21.287 Twentieth-Century Latin American Literature

Prereq.: Spanish IV
U (2) HUM-D **Next offered 1989-90**
3-0-9

Through reading poetry, novels, and short stories, students encounter a variety of creative responses to the complex and troubled reality of contemporary Latin America: from fantasy to social protest, from personal confession to the literary subversion of the language of demagoguery and mass media. Authors studied include Vallejo, Quiroga, Neruda, Arguedas, Rulfo, Borges, García Márquez, de la Parra, and Ferré.
E. Garrels

21.288 The Modern Short Story in Spain and Latin America

Prereq.: Spanish IV
U (1) **Next offered 1989-90**
3-0-6

Studies masterpieces of the short story produced in Spain and Latin America. Considers the short story as a genre with unique possibilities for expression, and also as a sociological phenomenon responding to particular historical circumstances affecting both writers and their readership. In addition, students write original stories based on analyses of narrative techniques employed by such authors as Borges, Cortázar, Martin Gaite, Aub, and Peri Rossi.
M. Resnick

21.289 Introduction to Contemporary Hispanic Literature (New)

Prereq.: Spanish IV or equivalent
U (1) HASS-D/HUM-D
3-0-9

Studies important 20th-centruy texts from both Spain and Latin America that represent the principal fictional genres — poetry, theatre, short story, and the novel. Approaches these texts from a variety of interpretive perspectives, including those of sociohistorical, psychoanalytic, feminist, structuralist, and myth criticism. Includes works by female writers Peri-Rossi, Bambal, Alegría, Morejón, Castellanos, and Tsuquets, and by male writers Lorca, Neruda, Vallejo, Quiroga, Unamuno, Aleixandre, García Márquez, Aub, and Vargas Llosa. Conducted in Spanish.
M. Resnick

21.290 Literature and Social Conflict: Perspectives on Modern Spain

Prereq.: Spanish IV
U (2) **Next offered 1989-90**
3-0-6

Considers how major literary texts illuminate principal issues in the evolution of modern Spanish society. Emphasizes the treatment of such major questions as the exile of liberals in 1820, the concept of progress, the place of religion, urbanization, rural conservatism and changing sexual roles, and the Spanish Civil War. Authors studied include Pérez Galdós, Pardo Bazán, Unamuno, Ortega y Gasset, Salinas, Lorca, La Pasionaria, and Falcon. Conducted in Spanish.
M. Resnick

21.292 Cervantes and His Age

Prereq: Spanish IV
U (2) **Not to be offered 1989-90**
3-0-6

Critics have long recognized Spain as the birthplace of the novel and have seen in *Don Quijote de la Mancha* the prototype for this genre. Concentrates on *Don Quijote* but also considers the author Cervantes as an outstanding example of the humanist in 16th-century Spain and Europe. Attention to Cervantes's humor and irony as well as his ideas on religion, justice, love, language, and artistic creation.
E. Garrels

21.293 History of the Spanish Language

Prereq.: Permission of Instructor
U (2)
3-0-6

Starts with the modern languages and proceeds to successively earlier stages. Includes general concepts of language change; specific phonological, morphological, and syntactic changes in the history of Spanish; the place of Spanish among Romance tongues; modern dialects; reading of representative texts of earlier periods. Discussion and readings in English and Spanish. Spanish III or equivalent normally provides sufficient preparation.
J. W. Harris

Literature in Translation

21.296 Introduction to European and Latin American Fiction

Prereq.: —
U (1) HUM-D
3-0-9

Studies great works of European and Latin American fiction. Attention to a variety of forms: the short story, novel, dialogue, and documentary. Emphasizes way in which the unique history of each country shaped the imaginative responses of its writers. Authors read include Flaubert, Borges, Brecht, Goethe, Cervantes, Laclos, Tolstoy, Stendhal, García Márquez, and Colette.
M. Resnick

21.297J Sex Roles in Fiction: Europe and Latin America

(Same subject as SP 432J)
Prereq.: —
U (1) HUM-D **Next offered 1989-90**
3-0-9

Examines the representation of sexual roles in fiction. Studies works by European and Latin American authors in their cultural and historical contexts. Themes emphasized include bourgeois women, women rebels, and redefinition of sex roles. Comparative analysis of works by Laclos, Fontane, Molière, Sor Juana Inés de la Cruz, Zola, Lorca, Wolf, Wittig, and Puig. Materials used include films by: Godard, Buñuel, Saura, M. v. Trotta.
M. Resnick, L. Kampf

21.299J New Women's Voices

(Same subject as SP 431J)
Prereq.: —
U (2) **Not to be offered 1989-90**
3-0-6

Contemporary women writers and the characters they create. Themes include the socialization of women in several patriarchal cultures, strategies of adaptation and/or rebellion, relationship to love and work, and search for identity. Experimentations with new narrative techniques to convey womens' experiences of the past and visions of the future. Novels, short stories, poetry, and films by Doris Lessing, de Beauvoir, Cixous, Toni Morrison, Margaret Atwood, Christa Wolf, Rita Mae Brown, Maria Luisa Bombal, Alice Walker, Ursula LeGuin, Von Trotta, and Duras.
E. Waldstein

21.300J Courtship Themes in Romance Literature

(Same subject as SP 434J)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Study of recurrent patterns of courtship in major works from France, Spain, Spanish America, Portugal, and Brazil. Themes such as the grand passion, marriage as a happy ending, the witty battle between unwilling lovers, and the contemporary breakdown of both conventional sex roles and the institution of marriage are examined. Authors include Fernando de Rojas, Cervantes, Balzac, Puig, Zola, the Three Marias, Machado de Assis, García Márquez, Chateaubriand, Wittig, and Bombal.
M. Resnick

21.301 Evil and Decadence in Literature

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Studies evil and decadence in literature, starting with Job, Petronius, and Dante. Emphasizes French and English authors including the Marquis de Sade, Byron, Shelley, Laclos, Baudelaire, Rimbaud, Flaubert, Lautréamont, Huysmans, Mirbeau, Wilde, Gide, Mann, Firbank, Corvo, Genet, Huxley, Golding. Students encouraged to read some of the texts in the original.
R. E. Jones

21.302 The Occult, Mysticism, Religious Heresy, and Literature

Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

Studies religious beliefs alternative to Christianity and their influence on Western literature of the last 200 years. The Tarot, doctrines of the Gnostics, Manicheans, Bogomiles, Cathars, Illuminists, Theosophists, Free Masons, Swedenborgians. Readings from Blake, Restif, Byron, Hugo, Balzac, Nerval, Baudelaire, Dostoevsky, Strindberg, Yeats, Jung, Dinesen, Poe, Kafka, Tryon, Fowles. Also related themes in art and music.
R. E. Jones

21.303 Twentieth-Century French Literature

Prereq.: —
U (1) **Not to be offered 1989-90**
3-0-9

Major writers and literary movements (Surrealism, Existentialism, Pataphysics) in France since 1900. Texts are chosen from the works of Gide, Proust, Céline, Malraux, Bernanos, Sartre, Camus, de Beauvoir, Giraudoux, Claudel, Anouilh, Beckett, Ionesco, Genet, Breton, Artaud, Queneau.
R. E. Jones

21.304 Modern European Drama

Prereq.: —
U (1) HUM-D **Next offered 1989-90**
3-0-9

Study of major playwrights, directors, and theorists of the theatre in France, Scandinavia, Russia, Germany, Italy, and Spain. Among the authors studied are Strindberg, Chekhov, Pirandello, Lorca, Claudel, Giraudoux, the Surrealists, the Expressionists, Brecht, Weiss, Arrabal, Sartre, Anouilh, Beckett, Ionesco, Genet. Students attend current productions in the Boston area.
R. E. Jones

21.305 The Modern Period: 1900-1970

(21.717)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

Role of the individual and the artist in modern society dominated by politics, war, and technology. Topics: reactions to 19th-century values, and especially those of Marx and Freud; role of myth; concepts of illusion and reality; sexual revolution and its implications; new humanism in art, music, philosophy, and literature. Authors read include Dinesen, Breton, Gropius, Marinetti, Gide, Proust, Pirandello, Jung, Giraudoux, O'Neill, Joyce, Eliot, Kafka, Malraux, Brecht, Beckett, Lawrence, Lessing, and Solzhenitsyn.
R. E. Jones

21.306 The German Cinema

Prereq.: —
U (2) **Not to be offered 1989-90**
4-0-5

Overview of the German film since its beginnings, emphasizing the New German Cinema of the 1970s. Weekly screenings. Lectures and discussions deal with technical and aesthetic as well as socio-historical problems. Students keep weekly journals based on thorough analysis of films as well as readings on social and historical background. Directors include Lang, Ruttmann, Pabst, Schlöndorff, Wenders, Herzog, Fassbinder, Lilienthal, M. v. Trotta. Conducted in English. Films shown with English subtitles.
M. Geisler

21.307 Modern German Novels in Translation

Prereq.: —
U (1) **Not to be offered 1989-90**
3-0-6

20th-century fiction from Germany, Austria, and Switzerland. Emphasizes major themes (bourgeois conventions and rebellion against them, role of the artist, individual and collective guilt, the metropolis, World War II and its aftermath), development of novel form, narrative structure, social and historical context. Authors include Thomas Mann, Kafka, Döblin, Grass, Christa Wolf. Showing of a film version of at least one novel.
Staff

21.310 Masterpieces of Hispanic Culture

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Subject studies major works of Hispanic literature, film, and art, including the *Poem of the Cid* , Cervante's *Don Quijote* (selections), Lorca's *Three Tragedies*, García Márquez's *One Hundred Years of Solitude*, short stories by Borges. Films by Bunuel, as well as paintings by Goya, Velazquez, and Picasso allow students to trace development of Hispanic Culture through focus on fanaticism, honor, and the grotesque, as well as on humor as a way to cope creatively with the world, or to escape from it. All readings and discussions in English.
E. Garrels

21.314 Russian Civilization: Tradition and Innovation (Revised Unit)

Prereq.: —
U (2)
3-0-6

Explores the symbolism of Slavic, especially Russian, fairy tales and mythology in light of universal mythological traditions. Conducts structural analysis of myths and folk tales, emphasizing recurrent patterns. Emphasizes the role of Slavic and Western folkloric traditions in the development of classical Russian literature from Pushkin and Gogol. Offers an overview of the transformations of traditional myths and motifs in 20th-century Russian literature.
Staff

21.315 Russian Short Story

Prereq.: —
U (1) **Not to be offered 1989-90**
3-0-6

The great development of Russian prose from Pushkin's *Tales of Belkin* and "Queen of Spades" through Gogol, Lermontov, Turgenev, Tolstoy, Dostoevsky, Leskov, and Chekhov. The growth of the short story as a structure as well as the history of themes and ideas pertaining specifically to this genre. To disclose differences and influences, a sampling of Western European prose, as well as modern Soviet stories, are analyzed. Some contrasting genres, such as Turgenev's novel *Rudin* and Pushkin's *Eugene Onegin* are discussed.
C. V. Chvany

21.317 Russian Novel of the Nineteenth Century (Revised Unit)

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

The development of the novel in Russia in the context of the evolving European novel. Emphasizes three major fictional modes: the historical, the psychological, and the satirical/realist novel and their European counterparts. Gives attention to the larger historical and social issues which determined the creative milieu of Pushkin, Lermontov, Gogol, Tolstoy, and Dostoevsky. Their relation to Sterne, Byron, and Walter Scott. Students with a knowledge of Russian encouraged to read some texts in the original.
Staff

21.318 Soviet Literature and Moral Issues

Prereq.: —
U (1) **Not to be offered 1989-90**
3-0-6

Study of the moral challenges by writers such as Solzhenitsyn, Grossman, and Chukovskaya; and of the ideological dilemmas of totalitarianism, socialism, and freedom in the post-Stalin period. The new point of view on war and patriotism represented by writers-participants in World War II. Poetry by Evtushenko and Voznesensky, and the poet's new identity.
E. Semeka

Senior Seminar

21.319 Senior Seminar for Majors in Foreign Language and Literature

Prereq.: —
U (2)
3-3-0

A workshop focusing on the specific task of thesis writing on topics in foreign literatures. Problems of methodology, organization, and critical writing addressed by means of faculty and student presentations. Gives special attention to research problems in foreign literatures including the identification of bibliographic tools and the acquisition of materials from foreign sources.
Consult C. J. Kramsch.

Studies in Language

21.320J Linguistic Theory and Second Language Acquisition

(Same subject as 24.948J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

See description under subject 24.948J.
W. O'Neill, S. Flynn

21.321J The Study of Language

(Same subject as 24.900J)
Prereq.: —
U (1, 2) HUM-D
3-0-9

See description under subject 24.900J.
S. Bromberger

21.322J Language and Its Structure

(Same subject as 24.901J)
Prereq.: 24.900J
U (2)
3-0-9

See description under subject 24.901J.
J. W. Harris

21.323 Language in Discourse

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Applies methods and insights of contemporary linguistics and related disciplines in exploring how communication takes place in spoken and written contexts. Discussion of such topics as speech acts, discourse presuppositions, metaphors in everyday language and in literature, dialogue, and narrative. Also considers the ways in which learners of a foreign language develop discourse competence in natural and instructional settings. Examples drawn from English and various foreign languages.
S. Flynn, C. Kramsch

21.324 Workshop in Translation

Prereq.: Permission of Instructor
U (2) **Next offered 1989-90**
3-0-6

For students who wish to translate short stories, essays, or poems into English. Class includes the study of technical, historical, and theoretical aspects of translation, as well as discussion of students' work. Critically examines models of translation, both classical and contemporary. Gives attention to linguistic problems of translation. Students complete a translation project which they elaborate in consultation with the faculty. Knowledge of any second language at an intermediate level or above is usually sufficient.
C. V. Chvany

English as a Second Language

21.326 English Ii: English as a Second Language

Prereq.: Placement test or Permission of Instructor
U (1, 2)
3-0-6

Continued development of skills in oral comprehension, speaking, reading, and writing. Activities, which include language laboratory work, reinforce understanding and lead to an increased ability to communicate.
S. Flynn

21.327 English III: English as a Second Language

Prereq.: Placement test or Permission of Instructor
U (1, 2)
3-0-6

Improves and refines accuracy, fluency, and style in both spoken and written English through use of American newspapers, radio, literary texts, videotapes, and movies. Also leads to better understanding of American cultures.
S. Flynn

21.328 English IV

Prereq.: Placement test or Permission of Instructor
U (2) **Next offered 1989-90**
3-0-9

Sharpening of both aural/oral and written communication skills. Systematic study of formal and informal discourse, word choice/use, and idioms. Informal discussion of language and American cultural issues through analyses of audio/video tapes and readings.
Consult S. Flynn.

21.331 Development of Listening and Speaking Skills: English as a Second Language

Prereq.: Placement test or Permission of Instructor
U (1, 2)
3-3-3

Provides intensive practice in idiomatic oral communication and listening comprehension for students who have mastered complex grammatical structures of English. Fall term focuses on presenting reports, explanations, and seminars to class using various approaches and styles. Gives some consideration to appropriate teaching methods. Valuable for those who intend to teach or lecture in English. Spring term focuses on the management of conversations within a variety of social contexts. Language laboratory assignments.
S. Flynn

21.333 Expository Writing I for Undergraduates: English as a Second Language (Revised Unit)

Prereq.: Placement test or Permission of Instructor
U (1)
3-1-8

Reading, discussing, summarizing, and paraphrasing articles and essays in nontechnical fields. Provides practice in basic writing skills by focusing on development of clear, well-organized paragraphs and essays. Also gives attention to vocabulary development and grammar. Special focus on strengthening skills of bilingual students.
Consult S. Flynn.

21.334 Expository Writing II for Undergraduates: English as a Second Language (Revised Unit)

Prereq.: Placement test or Permission of Instructor
U (1, 2)
3-1-8

Formulating, organizing, and presenting ideas clearly in writing. Reviews basic principles of rhetoric. Focuses on development of a topic, thesis, choice of appropriate vocabulary, and sentence structure to achieve purpose. Develops idiomatic prose style. Gives attention to grammar and vocabulary usage. Special focus on strengthening skills of bilingual students. Successful completion satisfies Phase I of the Writing Requirement.
S. Flynn

21.337 Workshop in Writing for Science and Engineering: English as a Second Language

Prereq.: Placement test
G (1, 2)
3-0-6

Analysis and practice of various forms of scientific and technical writing, from abstracts to journal articles. Detailed analysis of problems conveying technical information to a specialist audience. Comparable to 21.780 but methods designed to deal with special problems of those whose first language is not English.
Consult S. Flynn.

21.338 Workshop in Writing for the Social Sciences and Architecture: English as a Second Language

Prereq.: Placement test
G (1)
3-0-6

Advanced subject focusing on techniques, format, and prose style necessary for research papers. Emphasis on writing as required in fields such as economics, political science, and architecture. Methods designed to deal with special problems of those whose first language is not English. Consult S Flynn.

21.339 Workshop in Writing for Science and Engineering: English as a Second Language

Prereq.: Placement test
U (1, 2)
3-0-6

Analysis and practice of various forms of scientific and technical writing, from abstracts to journal articles. Short assignments — including abstracts, memos, progress reports, process analyses, and proposals — build toward a written term project and oral presentation. Comparable to 21.780 but special focus on strengthening skills of bilingual students. Successful completion satisfies Phase II of the writing requirement. Consult S. Flynn.

21.340 Workshop in Writing for the Social Sciences and Architecture: English as a Second Language

Prereq.: Placement test
U (1)
3-0-6

Advanced subject focusing on techniques, format, and prose style necessary for research papers. Emphasis on writing as required in fields such as economics, political science, and architecture. Short assignments — including letters of transmittal, memos, executive summaries, proposals, and progress reports — build toward a written term project and oral presentation. Special focus on strengthening skills of bilingual students. Successful completion satisfies Phase II of the writing requirement. Consult S. Flynn.

Special Topics

21.348 Special Topics in Foreign Languages and Literatures

Prereq.: —
U (1)
Arr.

21.349 Special Topics in Foreign Languages and Literatures

Prereq.: —
U (2)
Arr.

Advanced work in foreign languages and literatures for students wishing to pursue topics or projects not provided for by regular subject offerings. Before registering, student must plan course of study with appropriate instructor in the Section and secure the approval of the Section Head. Normal maximum credit is 6 units. Nine-unit projects are occasionally approved. If the work is to count toward the HASS Requirement, it must carry 9 units. Six-unit projects count toward the HASS Requirement only by special petition to the Institute Committee on Curricula. Consult Department headquarters.

See 21.008 The Bible

History

For other subjects related to history in addition to those given below, see Interdisciplinary Subjects, 21.901J-21.992.

European History

European History subjects are divided into two categories: Basic Fields: 21.350-21.361, and Special Subjects and Seminars: 21.365-21.386.

Basic Fields

21.350 The Ancient World: Greece

Prereq.: —
U (1) HUM-D
3-0-9

Political and cultural history of ancient Greece from the Near Eastern matrix to Alexander's world-empire. Includes Homer's world; the Ionian inventions of democracy, geometry, cosmology. Conflict with Persia and the inventions of history, drama, moral philosophy. Thucydides on the Athenian linkage of democracy, naval power, imperialism. Pros and cons, ancient and modern, of national unification under Macedon and of manifest destiny in East. Readings by ancient and modern historians; textbook.
H. A. T. O. Reiche

21.351 The Ancient World: Rome

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Roman republic in origin, structure, function. Roles of traditionalism, improvisation, Greek humanism. Outer success, yet internal polarization. Manipulation and terror as political instruments. Various perspectives on Pompey, Cicero, Caesar, Augustus and principate. Definitions of triumph and decline. Rostovtzeff on proletarization. Why no industrial revolution in third century? Conflict of religions, orthodoxy as value in theology and Roman law. Wide sampling of historians, ancient and modern.
H. A. T. O. Reiche

21.352 The Middle Ages I

Prereq.: —
U (2) HUM-D
3-0-9

Transitions from late Antiquity to the "First Europe," roughly from AD 300-1000. Examines changes in late Roman ideas and institutions and the formation of a Gallo-Roman and then of a distinctively European society. The issues of "civilization" and "barbarism," decline of literacy and urban centers, rise of the Church, Charlemagne, Vikings and Moslems, and the formation of feudal society.
R. M. Douglas

21.353 The Emergence of Europe: 1000-1300

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Process of recovery from damage suffered through 200 years of Magyar-Moslem-Viking invasions, and the formation of distinctively European values, ideas, and institutions. The High Middle Ages treated as an unstable unity: agriculture and new urban centers; Crusades; maturing feudalism, chivalric ideology, and kingship. New forms of literacy, the universities and the new formation of learned factions in the 13th century.
R. M. Douglas

21.356 History of the Western World I: 1500-1815

Prereq.: —
U (1) HUM-D
3-0-9

The evolution of the Western world between the end of the Middle Ages and the French Revolution. Topics: heritage of the Middle Ages; emergence of the new dynastic monarchies; the great explorations; the Renaissance in Italy and Northern Europe; the Protestant and Catholic Reformations; the Scientific Revolution; the Enlightenment; development of the bureaucratic state; the American and French revolutions.
D. B. Ralston

21.357 History of the Western World II: 1815-1970

Prereq.: —
U (2) HUM-D
3-0-9

Survey of the West during the era of its preponderence, the 19th and early 20th centuries, and during its subsequent retreat from world domination. Among the topics considered: the Industrial Revolution and its spread; liberalism and the modern nation state; unification of Italy and Germany; the "new" imperialism; World War I and the eclipse of Europe; the Russian Revolution and its consequences; the long armistice and World War II; "Pax Americana" and the post-war international order; the resurgence of the non-Western world.
D. B. Ralston, D. Forsyth

21.360 European Social History in the Nineteenth and Twentieth Centuries

Prereq.: —
U (2)
3-0-6

Studies the large-scale social and economic forces that changed the character of European society. Analyzes changes in population, diet, and health standards; mass migrations; class and family structures, roles of women and children; conditions of labor. The emergence of mass social and revolutionary movements in response to these changes is a major theme.
D. Forsyth

21.361 Europe in the 20th Century (Revised Unit)

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Examines changes in European political, social, and cultural life from the origins of World War I to the developments of the 1980s. Topics covered include World War I, the post-war revolutions, the counter-revolutions of Fascism and Nazism, the "normalcy" of the twenties, the Great Depression, the totalitarian states, World War II, reconstruction, Europe in the Cold War, the new consumer societies, relations with former colonies, and Europe in global perspective of the eighties.
W. B. Watson, D. Forsyth

Special Subjects and Seminars

21.365 The Renaissance in Italy

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Comparative studies in the development of Italian society, politics, and culture from the generation of Dante to the age of Machiavelli, emphasizing Florence and Venice. Reading drawn extensively from treatises and documents written by magistrates, merchants, and lawyers; artists, scholars, and men of letters of this period. Lectures and discussion; short papers, open-book final exam.
R. M. Douglas

21.366 The Renaissance and Reformation

(21.714)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Relationships between society and ideas in northern Europe during a century of acute social conflict, intellectual controversy, and uncommon creativity in nearly every area of thought and imagination. The process of "reformation" and "rebirth" examined in both religious and secular contexts. Readings from both "high" culture and "low" — Thomas More, Erasmus, Luther, Calvin, Rabelais, and Montaigne as well as from anonymous tracts and novels.
R. M. Douglas

21.369 Marx, Darwin, and Freud

Prereq.: —
U (1) HUM-D
3-0-9

In-depth historical and critical study of the attempts of Marx, Darwin, and Freud to investigate the natural and cultural development of humans and society; these attempts are treated as problems in creativity, intellectual history, the history and philosophy of the cultural sciences, and social thought.
B. Mazlish

21.370 Anarchism

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Readings from the classics of European and American Anarchism, and the study of anarchistic and anarchosyndicalist movements in Europe and the utopian anarchistic communities in the US. Examines all branches and versions of anarchism, from radical individualists to collectivist communitarians and various anarchistic critiques of modern industrial, bureaucratic society.
W. B. Watson

21.371J The Industrial Revolution: A Social and Cultural History (1750-1850)

(Same subject as STS 023J)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

Examines the industrial revolution itself and its impact on society and culture. Focuses attention on the intellectual, emotional, artistic, literary, and social effects, including implications for demographic and class structure and for the family. Presentations, where possible, in terms of individuals such as A. Smith, Malthus, Rousseau, Owen, Carlyle, St. Simon, and Fourier.
B. Mazlish

21.372 France 1789-1969: From the Revolution to Charles de Gaulle

Prereq.: —
U (2)
3-0-6

The French Revolution and the nature of the revolutionary and Napoleonic settlement; the search for stable political institutions to 1870; the factors underlying the stability of French society in the 19th century; the nature of the post-1870 republican synthesis and its breakdown in the 20th century; the efforts following World War II to reach a new political and social settlement.
D. B. Ralston

21.373 Modern Spain, 1469-1939

Prereq.: —
U (1)
3-0-6

Development of modern Spain from union of Castile and Aragon to triumph of General Franco in Spanish Civil War. Topics: growth and collapse of empire, struggle to establish a modern state, liberal experiment and oligarchic reaction, *pronunciamiento*-style rebellions, rule of new elites, collapse of monarchy and the Republican experiment, polarization and civil war.
W. B. Watson

21.375 The Making of Russia in the Worlds of Byzantium, Mongolia, and Europe (ca. 850-1800)

Prereq.: —
U (1)
3-0-9

Kievan state, tsardom of Muscovy, Petrine empire: periods of development of Russian historical identity within Byzantine, Eurasian steppe, and Western culturally or politically occupied spaces. The more lasting, defining influences of such experiences, together with geography, ethnology, and also great leaders (St. Vladimir, Genghis Khan and his Eurasian heirs, St. Sergius, Ivan the Terrible, Peter the Great, Catherine the Great) of Russian institutions and culture.
R. E. MacMaster

21.376 Imperial and Revolutionary Russia: Culture and Politics

Prereq.: —
U (1) HUM-D **Next offered 1989-90**
3-0-9

Analyzes Russia's social, cultural, political heritage, Eurasian imperialist and autocratic, ca. 1850. Reform, modernization — and national catastrophe: World War I, 1917 Revolution, Civil War of 1918-1921. Emphasizes emergence of radicalism (Populism, Communism) as a political culture: its role in the making of a new order, the USSR, in the Russian empire and in world history. Larger cultural themes concerning revolutionary consciousness; films, literature, social thought.
R. E. MacMaster

21.377 The Soviet Union: A Communist Society in Historical Perspective

Prereq.: —
U (2)
3-0-9

Marxism-Leninism, totalitarianism, and modernization in post-revolutionary Russia. Physical and ideological setting, the rise of Stalin, collectivization and industrialization, the terror and the purges, the process of de-Stalinization under Khrushchev and his successors, the transition from developing to industrial society, contemporary movements of dissent among intellectuals, religious groups, and nationalities. Problems of evaluating the changing Soviet Union and other Communist regimes, especially China.
R. E. MacMaster

21.378J Seminar in the Historical and Political Evolution of the Soviet Union

(Same subject as 17.609J)
Prereq.: Permission of Instructor
U (2)
3-0-6

A reading subject on the history and politics of the Soviet Union. Emphasizes internal developments rather than foreign policy. Students discuss the readings weekly. All required readings are in English, but supplementary readings in Russian are available for those students wishing them. Open to advanced undergraduates with some previous work in the Soviet area. Meets with 17.609 and 17.610.
L. R. Graham

21.379 Spanish Civil War, 1936-39

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Examines how traditional conflicts in Spanish society erupted into civil war, almost immediately provoking a worldwide response. Examines the consequences of the Civil War for Spain and the rest of Europe in light of political, social, and economic issues selected by students and the instructor. Special attention this year to literary responses to the war.
W. B. Watson

21.380 Hitler and Germany Since Bismarck

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

Bismarck, Kaiser Wilhelm II, the Weimar Republic: belated nation-building and industrialization, total war, revolution (left and right). The millenarian ideas, new political style, and rise of Nazism. The regime: from the friendly fascist internal German phase (to about 1938) to that of totalitarianism; imperialist aggression and world war; terrorist and racist genocide, especially of Jews. The Germanies since 1945: politics, economies, society.
R. E. MacMaster

21.383 Revolution in the 20th Century

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

The phenomenon of revolution as exemplified by the experiences of Russia, China, and possibly one or two other societies in the 20th century. Among the aspects of revolution studied are the weaknesses of the old order; the revolutionary ideologies; the origins and development of the revolutionary leadership; the takeover of power; the nature of the post-revolutionary social and political order.
D. B. Ralston

21.384 War, State, and Society in the Modern World

Prereq.: —
U (1)
3-0-6

A study of how war has been waged in the European world and elsewhere since 1500. Among the issues to be considered are the changing form and modes of war; the factors, both technological and sociopolitical, which have influenced them; the effects of war on the social and political structure of the countries involved.
D. B. Ralston

21.386 History and Psychoanalysis: Life-History

Prereq.: —
U (1)
3-0-9

Applies psychology, especially psychoanalysis, to the understanding of history. Emphasizes individual life-histories. First part: examination of psychological theories of Freud, Erikson, and others, and then of case studies, such as of Hitler and Gandhi. Second part: reports by members of the class on their own attempts at a life-historical study.
B. Mazlish

American History

American History subjects are divided into two categories: Basic Fields: 21.390-21.431 and Special Subjects and Seminars: 21.432-21.449.

Basic Fields

Introductory Series

21.390 American History to 1865

Prereq.: —
U (1) HUM-D
3-0-9

How and why the US had, by the time of the Civil War, developed a society, economy, politics, and geographical boundaries much like those of today. Examines closely the different colonial heritages of Spanish and British America; the American Revolution; the establishment and growth of the new nation; the Civil War, its background and impact. Readings are from modern scholarship as well as critical writings of the period by authors such as Winthrop, Paine, Washington, Madison, Garrison, H. B. Stowe, and Lincoln.
J. Namias

21.391 American History Since 1865

Prereq.: —
U (2) HUM-D
3-0-9

The rise of America to world power is chronicled by focusing on key internal as well as foreign policy developments and conflicts from Reconstruction through imperialism, the world wars, the civil rights movement, the women's movement, Vietnam, Watergate, and beyond. Assignments include speeches, novels, films, and oral histories as well as pertinent historical articles.
E. Fitzpatrick

21.392 War, Money, and Sex: Topics in American History

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Examines three central issues in American life through a topical rather than chronological approach as a means to understand changes in the role of morality, individual freedom and rights, power, the state, and cultural metaphors. Focusing on particular cases drawn from the entire span of American history, students address issues of evidence and interpretation in the historical discipline through studying speeches, paintings, advertisements, diaries, quantitative data, and scholarly works.
J. Namias, M. E. McGerr

Chronological Series

21.400 Colonial America

Prereq.: —
U (1)
3-0-6

North American history to 1763 with particular attention to the development of society and politics in the British colonies. Topics include the British, French, and Spanish empires; insurrections, witchcraft, and slavery; economic, social, and religious change; war, politics, and political ideology on the eve of the American Revolution. Readings are drawn from the most recent historical scholarship as well as documents of the time.
J. Namias

21.401 The American Revolution

Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

English and American backgrounds of the Revolution; issues and arguments in the Anglo-American conflict; colonial resistance and the beginnings of Republicanism; the Revolutionary War; constitution writing for the states and nation; effects of the American Revolution. Concerned primarily with the revolutionary origins of American government. Readings emphasize documents from the period — pamphlets, correspondence, the minutes or resolutions of resistance organizations, constitutional documents and debates.
P. Maier

21.402 The Establishment of the American Republic, 1787-1850

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

Examines efforts to establish a new nation; work out the meaning of republicanism; fulfill the ideals of equality and freedom; maintain social order; and create a democratic culture in an era of rapid social, economic, and technological change. During that era, the country expanded from the Mississippi to the Pacific, and produced a railroad system, frontier revivals, the Graham cracker, Walt Whitman, P. T. Barnum, the modern factory, political parties, and the abolitionist movement.
A. D. Kaledin

21.403 The Civil War and Reconstruction

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Anti-slavery and the intensification of sectionalism in the 1850s; the secession crisis; political and military developments in the Civil War years; the "reconstruction" of Southern politics and society after Appomattox.
M. E. McGerr

21.404 America in the Industrial Age, 1877-1917

Prereq.: —
U (2)
3-0-6

The social and political implications of industrialization from the end of Reconstruction to World War I. Focus is on the way in which conflicts of race, culture, class, and region reshaped domestic politics and governance and projected the nation into world power. Includes the emergence of the corporate economy; labor and the workplace; transformation of the political parties; populism; imperialism; progressivism; and rise of the regulatory state. Readings from fiction and tracts of the period and historical studies.
E. Fitzpatrick

21.405 America in the Twenties and Thirties, 1917-1941

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

American politics, society, and culture during World War I, the 1920s, and the Great Depression. Topics include impact of the war on American society; changing gender roles, race, and ethnicity; economy and culture of the 20s; impact of the Depression; and significance of the New Deal. Readings in both historical and literary materials, accompanied by contemporary films.
S. J. Deutsch

21.406 America Since World War II, 1941 to the Present

Prereq.: —
U (1)
3-0-6

The transformation of American politics and society during and after World War II. Topics include the deepening American involvement in world affairs; expansion of the role of government; the civil rights movement, the new left, and the women's movement; political and cultural crises of the 1960s and 1970s; rise of the right.
E. Fitzpatrick

Topical Series

21.409 American Ideas and Culture: From the Puritans to the Civil War

Prereq.: —
U (1)
3-0-9

American thought and culture from the 17th-century Puritans to the Civil War, as expressed in the work of various classic American writers, thinkers, artists (e.g., Edwards, Franklin Jefferson, Adams, Madison, Emerson, Whitman) and as embodied in American institutions, social life, and law. The influence of social structure and material circumstance on ideas in America. The emergence of the fundamental myths of American culture.
A. D. Kaledin

21.411 American Ideas and Culture: The Modern Age, 1920-1980

Prereq.: —
U (2) HUM-D
3-0-9

American thought and culture from the Jazz Age and the "Lost Generation" of the 1920s through the counterculture of the 1960s and the neoconservatism of the 1970s. The fundamentalist-modernist conflicts of the 1920s and the 1970s-1980s. Developments in religious and political thought; changing ideas about men, women, sexuality, ethnicity, race; the effect of technology and professionalism on cultural life and institutions; the development of a youth culture; the impact of black culture; changes in art, literature, and popular culture.
A. D. Kaledin

21.412J American Urban History I

(Same subject as 11.013J)
Prereq.: —
U (1) HUM-D
3-0-6

See description under subject 11.013J.
R. M. Fogelson

21.413J American Urban History II

(Same subject as 11.014J)
Prereq.: —
U (2) HUM-D
3-0-6

See description under subject 11.014J.
R. M. Fogelson

21.414 History of the American West

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Examines the myth and history of the West before and after it became "American," through memoirs, fiction, articles, movies, and works of history. From Hopis and Hispanics to Hollywood, cowboy culture to Silicon Valley, it traces the impact of the United States on the West and the impact of the West on the United States.
S. J. Deutsch

21.416J American Women's History

(Same subject as SP 420J)
Prereq.: —
U (1) HUM-D
3-0-9

Starting with Pocahontas and ending with the 1980s, students examine the female experience in the US, focusing on issues of power, race, ethnicity, and class, and on concepts of work, family, and sexuality, with their ramifications for the world of both sexes. The reading combines articles by current scholars with a large proportion of primary documents (diaries, memoirs, interviews, fiction). In addition, a movie is shown.
E. Fitzpatrick

21.418 The Immigrant Experience: Race and Ethnicity in the US, 1880-1980

Prereq.: —
U (2)
3-0-6

Includes the background both of the immigrants and of the Americans who met and tried to "Americanize" them; definitions of "American"; mass migration movements including those of blacks, Hispanics, and Asians; Federal immigration policy; life in the immigrant community, and immigrant labor.
J. Namias

21.420 The Vietnam War, 1945-1975

Prereq.: —
U (2)
3-0-6

Military, political, and social history of Indochina conflict, with emphasis on American involvement. Includes Vietnamese nationalism and communism, American global interests, strategy and tactics, the imperial presidency, and the antiwar movement. Assigments include oral histories, military memoirs, government documents, and films.
M. E. McGerr

21.431 The Founders of the Republic

Prereq.: —
U (1)
3-0-9

A study of politics and theory, personality and power in the early decades of the American Republic, as focused by the ideas and dreams, the private lives and public careers, the ambitions and rivalries of the major Founders — Washington, Adams, Jefferson, Hamilton, and Madison. Readings are mostly from the writings of the aforementioned authors, including a biography of each.
A. D. Kaledin

Special Subjects and Seminars

21.432 Religion in America

Prereq.: —
U (2)
3-0-9

A history of religious life and thought in America, emphasizing the 19th and 20th centuries. Main topics include developments in the major churches; the evangelical-revivalist tradition from Jonathan Edwards to Billy Graham; original American religions (e.g., Mormonism); recent religious developments (e.g., Eastern religions, therapeutic faiths, born-again Christianity, satanic cults). The place of religion in American culture and politics.
A. D. Kaledin

21.433J Industrialization and Cultural Change in 19th-Century America

(Same subject as STS 058J)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

See description under subject STS 058J. Consult R. Douglas.

21.435 The American Psyche

Prereq.: —
U (2)
3-0-9

A study of 1) "What is an American?," i.e., the question of identity, starting with the examination of the concept itself and then of efforts (e.g., by Tocqueville, Erikson) to describe and analyze such a presumed character; and 2) the application of psychological approaches to individuals (e.g., Jefferson, Lincoln), to persistent themes (e.g., the frontier hero, or cowboy), and to collective phenomena and events (e.g., slavery, the American Revolution).
B. Mazlish

21.439 Fortress America: The Rise of the American Military, 1945-1975

Prereq.: —
U (2)
3-0-6

Critical examination of the development of a large permanent military establishment in the post-war period and the consequences of this development for both domestic and international policies. Topics include ideological and political justifications for military establishments, changing force structures, changing role of military institutions in foreign policy, defense budgets, impacts of defense spending.
W. B. Watson

21.441J Does Technology Drive Politics?: The Decision to Build the H-Bomb (New — Context Subject)

(Same subject as 8.204J)
Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

In considering the relationships among science, technology, and society, no subject is more important or more illuminating than the decision of the US government in 1950 to develop the H-bomb in response to the first Soviet A-bomb test. The decision was made by President Truman and his advisors despite the recommendation of the Atomic Energy Commission. Students study the physics and history of the era; each researches in depth one of the decision makers (e.g., Oppenheimer, Lillienthal, Acheson, Truman, and others). May *not* count toward HASS Requirement.
S. Deutsch, A. M. Bernstein

21.449 Introduction to American Studies: American Popular Culture

Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

Introduction to problems and methods in the interdisciplinary study of American culture. Topic for 1988-89: the study of American popular culture. 1) Theories of popular culture, and the history of American popular culture from Barnum to World War II; 2) American popular culture since 1945 — general themes and developments with evidence drawn from TV, movies, rock and country music, comedy, "amusement" parks, popular fiction, and popcult "stars"; 3) the institutions, technology, and business of popular culture.
A. D. Kaledin

History of Africa, East Asia, Latin America, and the Middle East

History of Africa

21.450 The History and Culture of the African Heritage

Prereq.: —
U (2) HUM-D
3-0-9

The history of Africa, with attention to the peopling of black Africa, Africa's relationship with the New World since 1492, the slave trade, the emergence of Africa into the modern world, and the crisis in South Africa.
R. W. Kilson

21.451 Twentieth-Century Africa: Past, Present, and Future

Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

The political emergence of modern Africa, concentrating on colonial rule, African resistance and rebellion; the triumph of independence; the period of instability, decay, and crisis; struggle for South Africa; and the crisis of independent Africa in the 1980s.
R. I. Rotberg

21.452 Comparative African Politics: Crises in Southern Africa

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Political and historical problems of South Africa, Namibia, Zimbabwe, and other countries. Particular attention paid to the development of apartheid in South Africa and to its possible future abolition. Also, closely examines the liberation struggle in southern Africa, its successes and failures. Role of American and European policy toward southern Africa looked at critically. Analyzes the position of American corporations.
R. I. Rotberg

21.455 Politics and History as Literature: The African and Caribbean Experience

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

The novels of Africa and the Caribbean mirror the history and politics of both areas in earlier as well as contemporary periods. In 1988-89, this course emphasizes the problems of South Africa and the mirroring and analysis of its inner complaint through literature. Among the authors read are Abrahams, Achebe, Beti, Cary, Coetzee, Gordimer, Greene, Lamming, Mulaisho, Naipaul, Ngugi, Paton, Romaine, and Thoby-Marcelin.
R. I. Rotberg

21.457 Imperialism and Colonialism in International Relations

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

European and American hegemony in the Third World, varieties of foreign political and economic rule and intervention, the intellectual arguments, and the economic and political response of the Third World.
R. W. Kilson

History of East Asia

21.460 East Asian History: China

Prereq.: —
U (2) HUM-D **Next offered 1989-90**
3-0-9

History of Chinese civilization from the Shang through the Ch'ing dynasties (1500 BC-AD 1911). Topics include the origins of Chinese civilization, Confucianism and Taoism, the early empire, the effects of Buddhism, the T'ang-Sung transition, popular literature, Ch'ing conquest and the late empire, 19th-century rebellion and decline.
P. C. Perdue

21.461 East Asian History: Japan

Prereq.: —
U (1) HUM-D
3-0-9

History of Japanese civilization from its origins to the present, concentrating on the period of rapid transformation from the late Tokugawa period through the end of the American occupation (1800-1954). One major theme is the distinctiveness of Japanese society and the nature of foreign influences on it.
P. C. Perdue

21.462 Social and Economic Transformation in China, A.D. 900-1900

Prereq.: —
U (1)
3-0-6

In the year 1000, China was the world's most populous, most urbanized, and most technologically advanced civilization. By 1900, it had become one of the world's poorest nations. Why? Students examine long-term social and economic change during this period, including geography, demography, commerce and state economic policy, technology, agriculture, popular culture, and collective action, concluding with a discussion of the legacy for economic modernization in China today.
P. C. Perdue

21.463 Revolution in China and Vietnam, 1850-1980

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Both China and Vietnam underwent a protracted process of social transformation and revolutionary upheaval in the 19th and 20th centuries, and both successfully conducted peasant revolutions directed against Japan France, and the US. The course compares their revolutionary experiences, their resistance to imperialism, and the socialist societies established after the revolution.
P. C. Perdue

21.464J Industrial Competition in the US and Asia (New — Context Subject)

(Same subject as 3.08J)
Prereq.: —
U (2)
3-0-6

Examines causes of economic efficiency and international efficiency and international competitiveness in economies of the US and Asia — particularly China and Japan — considering relative importance of technological, economic, social, and historical factors. Topics include costs of production, product quality, organizational structures, labor relations, and the educational system. Case studies of selected industries such as automotive, steel, electronics, computers, and biotechnology. May *not* count toward HASS Requirement.
P. C. Perdue, J. P. Clark

21.465 Family, State, and Economy in East Asian History (New)

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Focuses on three themes which are vital to the study of East Asian societies (primarily in China and Japan). 1) How have Confucian ideas on the family been put into practice by East Asian societies? 2) How has the intellectual elite voiced its criticism of the state in imperial and modern times? 3) What factors in 18th- and 19th-century China and Japan have promoted or obstructed economic and technological development?
P. C. Perdue

History of the Middle East

21.480 The Middle East, Islam, and the West

Prereq.: —
U (1) HUM-D
3-0-9

Surveys Middle East/Islamic history. Part I examines the Classical Age of Islam through themes of Arab expansion and adaptation. Stresses nomadic-urban encounters, sociopolitical institutions, Christian and Jewish minorities, cultural-scientific achievements and their transmission to Europe. Part II examines later Islamic states and their background to modern Middle East. Emphasizes Europe's dramatic expansion after 1800 and Middle East reactions to it, including rise of modern nationalisms and Islamic movements.
H. Kayali

21.481 The Middle East in the Twentieth Century

Prereq.: —
U (2) HUM-D
3-0-9

Surveys major political, socioeconomic, and cultural changes in post-World War I Middle East through the lenses of religion, state, and nationalism. Investigates interwar independence struggles against Europe, followed by the emergence of American-Soviet rivalry, radical nationalist and socialist movements, and the growth of modern states and societies after 1945. Examines contemporary problems in historical perspectives: Arab-Israeli conflict, Lebanon War, oil and regional security, Iranian revolution, Islamic fundamentalist movements.
H. Kayali

21.483 Nationalism, Imperialism, Revolution: The Middle East

Prereq.: —
U (1)
3-0-6

The Middle East's experience with nationalism in the 20th century. Examines theories and varieties of nationalism, imperialism, and revolution. Focus on Arab nationalism: its origins; character of independence movements; rise of radical pan-Arabism and relationship with radical Islamic and Marxist movements; special place of Palestinian nationalism; and retreat from pan-Arabism after 1970. Comparisons with Turkish, Iranian, and other Third World nationalisms, and with Islamic fundamentalist movements.
P. S. Khoury

21.484J Modern Egypt and Iran: Islam and Politics in Historical Perspective

(Same subject as 17.562J)
Prereq.: —
U (2)
3-0-6

A comparative perspective is used to examine the role of Islam, the human and physical environment, and imperialist rivalries in shaping the character of state and society in 20th-century Egypt and Iran. Explores forces and events that toppled the Egyptian monarchy in 1952 and the Shah of Iran in 1978-79, and which brought about Nasser's and Khomeini's revolutions. Examines the social/ideological bases and aims of contemporary Islamic movements, their approaches to women, economic development, and international relations. Open to graduate students.
P. S. Khoury

21.485J Politics, Technology, and Development in the Middle East

(Same subject as 1.255J, 4.715J, 11.488J, 17.558J, STS 509J)
Prereq.: —
G (1)
3-0-9

See description under subject 17.558J.
N. Choucri, F. Moavenzadeh, R. Lewcock, W. Porter

21.490 Special Topics in History

Prereq.: —
U (1)
Arr.

21.491 Special Topics in History

Prereq.:—
U (2)
Arr.

Individual supervised work for students who wish to study topics not covered in the regular history offerings. Before registering for this subject, a student must plan a course of study with some member of the History Faculty and secure approval from the Head of the History Faculty. Normal maximum is 6 units; to count toward the HASS Requirement, 9 units are required. Nine-unit projects are occasionally approved.
Staff

21.492 Advanced Topics in History (New)

Prereq.: —
G (1)
Arr.

21.493 Advanced Topics in History (New)

Prereq.: —
G (2)
Arr.

Individual supervised work for graduate students on a topic or field of history not covered at the graduate level in the regular history offerings. Before registering for this subject, a student must plan a course of study with a member of the History Faculty and secure the approval of the head of the History Faculty.
Staff

21.494 Seminar in Historical Methods (New)

Prereq.: Two History subjects
U (2)
3-0-6

Examination of the methods of historical research and analysis. Begins with classics of historical writing from Thucydides to present, followed by close examination of changes made in historical research and interpretation in the 20th century, including the contributions of the social sciences to historical research; the impact of quantitative and computer techniques; oral history methodologies; history "from the bottom up" and the new social history. Open to all students, but required of history majors and minors.
W. B. Watson

21.498J Theories and Methods in the Study of History (New)

(Same subject as STS 102J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Examines the history of history, i.e., "What is History?" in a philosophical manner; and seeks to become familiar with various approaches, e.g., quantitative, psychological, Marxist, Weberian, etc. (Open to qualified undergraduates.)
B. Mazlish

See 21.008 The Bible

Anthropology/Archaeology

The anthropology and archaeology subjects described below are grouped within four areas: introductory, social anthropology, technology in cultural context, and archaeology. Students are encouraged to take subjects from each of the groups for a fuller overview of the field.

Introductory

21.50 Introduction to Anthropology

Prereq.: —
U (1) HASS-D/HUM-D
4-0-8

An examination of the differences and similarities among nomadic hunters-gatherers, tribal peoples, peasants, and modern complex societies. Is there a common human nature behind the apparent diversity? Different cultural values are seen in relation to ecology and social structure. The impact of modernization and Western influences also studied.
M. Diskin

21.503 Introduction to Archaeology: Paths to Civilization

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

The path to and development of states and empires in various parts of the world — an overview of patterns in prehistory. Focus on how humankind exploited the environment; shaped settlements; and formed larger, increasingly more complex social and political organizations in the Americas, Southwest Asia, and China.
A. Steinberg

21.504 Approaches to Archaeology

Prereq.: —
U (1)
2-4-6

Studies various analytical techniques and approaches used to "tease" the past out of archaeological remains. Lectures and discussions on methods of archaeology and their theoretical underpinnings. Weekly lab sessions devoted to analyzing artifacts and data, and testing the tools of archaeology. Topics include surveying and locating sites, excavation strategies, dating techniques, analyzing ceramic and lithic artifacts, studying organic remains, statistics, uses of inference, and experimental archaeology. Consult A. Steinberg.

21.505 Human Origins and Adaptations

Prereq.: —
U (2)
3-0-6

Examines the dynamic interrelations among physical and behavioral traits in humans and environment, culture, and social practices to provide an integrated framework for studying human biological diversity. Topics include issues in evolution and adaptation; fossil and cultural evidence for human evolution from earliest times through the Pleistocene; evolution of tool use, social behavior, and organization; territoriality and aggression; sex roles; concepts of race. Consult A. Steinberg.

21.506 Evidence and Argument in Anthropology (New)

Prereq.: —
U (2) HASS-D/HUM-D
3-3-6

Anthropological evidence ranges from the microstructure of ancient Andean metal artifacts to Amazonian Indian botanical taxonomies to peasant rebellion in SE Asia. Analysis of this rich body of evidence shares the methods of science but also utilizes approaches unique to anthropological concerns. In lecture and discussion, emphasis is given to the systematic nature of both types of anthropological research. In the laboratory, students design and execute their own projects within the anthropological tradition.
M. Diskin, H. Lechtman

21.510 Seminar in Anthropological Method and Theory (New)

Prereq.: Major or minor in Anthropology, or permission of instructor
U (2)
3-0-9

Discussion seminar focusing on core issues and approaches in anthropology/archaeology. Students read a combination of theoretical and descriptive works. Topics include models and methods, production and kinship organization, the modern world system, gender and social interpretation, and competition and individualism. Consult J. Howe.

Social Anthropology

21.511 Magic, Shamanism, and Witchcraft

Prereq.: —
U (1)
3-0-9

A look at several interrelated aspects of religious belief and practice, especially those often considered the very antithesis of "scientific": witchcraft and sorcery, magic and divination, curing rites, shamanism, messianic movements, and the rise of new religions. Material drawn from Western, non-Western, modern, and bygone and "primitive" societies.
J. Howe

21.512 Myth, Ritual, and Symbolism

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

People everywhere construe their worlds symbolically, and express themselves in myth and ritual. Focuses on the social and political uses of myth, ritual, and symbol in both traditional and modern societies, and relates theories about them to everyday, practical concerns.
J. Howe

21.514 Communities in Crisis

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

What happens when a community is severely stressed? Investigates crises in several Western and non-Western communities, and the attempts made to resolve them by political, religious, or other means. Consult J. Howe.

21.521 Central American Society

Prereq.: —
U (1)
3-0-6

Central America's heterogeneous population includes Indians, Afro-Americans, and Europeans. Spain, England, and the US have been significant influences. Focuses on land use and agrarian relations, foreign intervention, repression, and revolution in an effort to explain the present crisis.
M. Diskin

21.523 Agrarian Society

Prereq.: —
U (2)
3-0-6

A view of world history as seen from the countryside. From a study of the ancient world (Greece, Rome) and feudalism, considers modern peasant communities and plantations, and examines farming systems, family structures, political rights, and rural values. Studies rural responses to urban pressures, including modernization and revolution.
M. Diskin

21.530J The Contemporary Family

(Same subject as SP 456J)
Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

The role of the family in human evolution, and as a symbol in our own social and political lives. Topics include: sex, marriage, and parenting; the labor market; class, race, and ethnicity; and the family's probable future.
J. E. Jackson

21.531J Sex Roles: A Comparative Perspective

(Same subject as SP 455J)
Prereq.: —
U (1)
3-0-9

Each culture, including our own, treats humankind's sexual dimorphism in a distinctive way. Considers several theories of gender (Marx and Engels, Freud, and others), as well as such topics as the origin of the sexual division of labor, child-rearing, symbols of sexuality, and gender and politics.
J. E. Jackson

Technology and Cultural Context

21.534J Modern Times

(Same subject as STS 056J)
Prereq.: —
U (1)
3-0-6

Anthropologists, famous for excursions among exotic peoples, increasingly study one of the most bizarre societies of all — our own. A cross-cultural perspective taking into account both "primitive" societies and other industrialized ones helps us to understand our own body rituals, ethnic divisions, myths, living arrangements, rites of education, sense of time, and scientific cosmology. Consult J. Howe.

21.536J Cross-Cultural Studies of Scientific and Technological Institutions

(Same subject as STS 057J)
Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

See description under subject STS 057J. Consult K. Keniston.

21.540 Technology and Culture

Prereq.: —
U (2) HUM-D
3-0-9

Humans are cultural creatures who use tools to control their physical and social environments. How are technical knowledge and expertise embedded in other aspects of a culture? What are the sources and effects of technological innovation — and why does it sometimes lead to decreasing control of the environment? Explores such questions through case studies ranging from Eskimo hunters to "high-tech" operations. Consult J. Howe.

21.543J History and Anthropology of Materials Technology

(Same subject as 3.17J)
Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

See description under subject 3.17J.
H. N. Lechtman, L. W. Hobbs

Archaeology

These subjects are divided into regional and topical, and subjects taught under the auspices of the Center for Materials Research in Archaeology and Ethnology (CMRAE).

Regional

21.550-21.552 The Archaeology of the Americas I, II, III, need not be taken in any particular order, nor is one a prerequisite for the others.

21.550 Archaeology of the Americas I: First Americans

Prereq.: —
U (1)
3-0-6

Indian cultures in North America from Paleo-Indian entry into the New World over 10,000 years ago to European contact. Includes Pleistocene Paleo-Indian big-game hunters, development of regional differences among Indian groups, major pre-Columbian cultures (e.g., Southwestern Cliff Dwellers, Southeastern Moundbuilders), art and ritual (e.g., rock art, ancient astronomy), relation of prehistoric Indian cultures to modern Indian groups.
Consult A. Steinberg.

21.551 Archaeology of the Americas II: Ancient Mesoamerica

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Ancient societies of Mexico and Central America, from the earliest times to the Aztec and Maya in A.D. 1500. Emphasizes understanding major changes in human life in the New World: evolution from gathering to agriculture, origin of pottery and other technological innovations, and the origins of cities, states, and empires.
Consult A. Steinberg.

21.552 Archaeology of the Americas III: The Ancient Andean World

Prereq.: —
U (1)
3-0-6

Examines development of Andean civilization which culminated in the extraordinary empire established by the Inca. Archaeological, ethnographic, and ethnohistorical approaches. Particular attention to the unusual topography of the Andean area, its influence upon local ecology, and the characteristic social, political, and technological responses of Andean people to life in a topographically "vertical" world. Characteristic cultural styles of prehistoric Andean life.
H. N. Lechtman

21.553 Archaeology of the Middle East

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Focus on the rise of cities and empires in various areas of the Middle East including Anatolia, the Levant, Mesopotamia, and Iran. Using archaeological and written sources, examines why such complex societies arose in this area. Considers the role of temples and religious hierarchies, of crafts and trade in luxury goods, of writing and bureaucracies, of class stratification, in the rise of early empires.
Consult A. Steinberg.

21.554 Archaeology of Egypt

Prereq.: —
U (1)
3-0-6

Egypt was the home of one of the first and most spectacular civilizations in the world. Focuses on how that civilization developed. Traces Egypt's past from its first inhabitants through the reign of the Pharaohs with special emphasis on 1) how complex political systems evolved from the simple villages of predynastic days; and 2) how agriculture developed in the Nile Valley and how it contributed to the growth of civilization. Also considers the development of religion, art, and writing systems.
Consult A. Steinberg.

Topical

21.560 The Archaeology of the City

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

That unique human construct, the city, is the focus. After discussing different approaches to the study of the city, students look at examples from the Near East, China, and the Greco-Roman world to see how they evolved, differed, and decayed. Physical and social plan, forces that shape them, the present and future of cities are among the topics discussed.
A. Steinberg

21.561 The Decline of Empires

Prereq.: —
U (2)
3-0-6

After examination of basic institutions and processes of empires from modern sociological literature and recent examples, we derive some generalities about how and why empires disintegrate. Considers frontiers, military power, bureaucracy, ruling elites, religions, population growth, raw materials and markets, and urbanization. Generalities tested against examples chosen from ancient and medieval times including Persia, Greece, Rome, Byzantium, and China.
A. Steinberg

Graduate Subjects

For Program in History and Social Study of Science and Technology

21.570J Theory and Method in the Study of Social Institutions (New)

(Same subject as STS 502J)
Prereq.: —
G (2)
3-0-9

Proseminar in social science theory and method, with emphasis on ethnographic approaches. Introduces pioneering works by Durkheim, Mauss, Malinowski, Marx, Weber, Levi-Strauss. Contemporary interactionist, interpretational, cognitive, and structuralist approaches. Ethnographic methodology and the fieldwork encounter. Materialist vs ideational theories.
J. Howe, J. Jackson

Center for Materials Research in Archaeology and Ethnology

CMRAE is an inter-institutional center whose subjects are listed with the Anthropology/Archaeology offerings and are open only to graduate students and seniors by permission of the instructor.

21.582 Materials in Ancient Societies

Prereq.: Permission of Instructor
G (2)
3-6-3

The laboratory analysis of archaeological artifacts helps us understand the societies that produced them. This seminar-laboratory subject provides in-depth study of a single class of material — e.g. ceramic, metal, stone — and the technologies ancient societies used to transform such materials of nature to items of culture. Laboratories stress the microstructural analysis of archaeological materials and the production histories of artifacts; seminars investigate topics that relate materials selection and processing to environment, exchange, aesthetics, political power, and cultural values.
H. N. Lechtman

Special Topics

21.591J Music and Art: Contexts for Hearing and Seeing (New)

(Same subject as 21.611J)
Prereq.: —
U (1) HASS-D/HUM-D
4-0-8

See description under subject 21.611J.
A. Steinberg, J. Bamberger

21.596 Special Topics in Anthropology/Archaeology

(21.598)
Prereq.: Any two subjects in Anthropology or Archaeology
U (1)
Arr.

21.597 Special Topics in Anthropology/Archaeology

(21.599)
Prereq.: Any two subjects in Anthropology or Archaeology
U (2)
Arr.

Topics in anthropology or archaeology not included in other subjects. Students electing this subject must secure the approval of the chair of the Anthropology/Archaeology Program. Normal maximum is 6 units; to count toward HASS Requirement, 9 units are required. Exceptional 9-unit projects occasionally approved. Consult J. Howe.

21.598 Advanced Topics in Anthropology/Archaeology (New)

Prereq.: —
G (1)
Arr.

21.599 Advanced Topics in Anthropology/Archaeology (New)

Prereq.: —
G (2)
Arr.

For graduate students who wish to pursue special studies or projects at an advanced level with a member of the Anthropology/Archaeology faculty. Consult J. Howe.

See 21.008 The Bible

Music

The Music subjects described below are grouped within six areas: introductory, interdisciplinary, history/literature, theory/composition, performance, and seminars/tutorials.

Although most students start with introductory subjects, those who have vocal or instrumental training or extensive exposure to music are encouraged to begin at a higher starting level.

Introductory Subjects

21.60 Introduction to Music (Revised Content)

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-3-6

Gives students a broad overview of Western music from the Renaissance to the present. Enhances the listening experience by developing analytical hearing and an understanding of major styles and genres. Fundamentals of musical organization; major composers and works placed in context — social, cultural, as well as musical. Weekly lab sessions (Athena Music Lab; Listening Lab) for hands-on experience with making and performing music.
Coordinator: M. Marks

21.601 Fundamentals of Music

Prereq.: —
U (1, 2)
3-3-3

Study of fundamental concepts and basic vocabulary of rhythm, melody, and harmony with particular emphasis on sight-singing and dictation. In support of this, a minimum of three laboratory hours in aural, keyboard, or sight-singing skills included.
S. Erdely, P. Ambush

21.602 Basic Musicianship

Prereq.: —
U (1, 2)
3-2-4

An integrated approach to basic musicianship, which aims at deepening students' understanding of fundamental musical processes. Work includes many kinds of listening exercises, group sight-singing, in-class instrumental performance, and a keyboard laboratory for elementary score reading and beginning keyboard harmony. Intended for students who are familiar with notation and have some instrumental/ listening experience. Students with considerable experience in performance and basic theory should try to begin with 21.641.
B. Burleigh

21.605 Developing Musical Structures

Prereq.: —
U (2) **Next offered 1989-90**
3-3-6

What are the basic "primitives" of musical structure? How are these developed to create the complexity of great works? What is the role of analysis and description in developing perceptual problem-solving abilities? Using the LOGO computer music synthesizer system as a "tool kit," students make multidimensional procedural analyses of a few significant pieces. With these as models, new pieces are designed and generated by turning the procedural analyses into "procedural composition."
J. S. Bamberger

Interdisciplinary Subjects

21.611J Music and Art: Contexts for Hearing and Seeing (New)

(Same subject as 21.591J)
Prereq.: —
U (1) HASS-D/HUM-D
4-0-8

Examination of a limited number of paintings and musical compositions in a wide variety of contexts to see how the artist/composer interacts with his various surroundings and how they affect his work. Contexts include structural-formal (materials and forms), sociocultural (role of artist/composer in society, patronage, function of art work); also the viewer/listener's personal vantage point and how that affects understanding of the work (the cognitive/psychological context). "Truth" in art, as in any field, is in the eye/ear of the beholder.
J. Bamberger, A. Steinberg

21.612J Learning to Design and Designs for Learning (New — Context Subject)

(Same subject as 11.017J)
Prereq.: —
U (2)
3-6-3

How generalizable is design knowledge? How is it acquired? What are the elements, relations, exemplars, and representations that guide it? We build a culture of reflection on questions like these, starting with a few simple design tasks; then go on to designing in two specialized fields — mechanical structures and computer programming. On the basis of our experience in initial tasks and specialized areas, we examine similarities and differences in design processes across media and domains of expertise. May *not* count toward Hass Requirement.
J. Bamberger, D. Schon

21.615 Musical Acoustics

Prereq.: One Music Subject
U (1, 2)
3-0-6

An introductory treatment of physical and psychological aspects of musical perceptions and production. Physical principles of woodwind, brass, string, and percussion instruments, as well as the human voice are studied. Psychophysical topics such as the perception of pitch, loudness, timbre, and rhythm are covered. Sound propagations and acoustical properties of rooms and concert halls and criteria for their proper functioning are discussed. Electronic applications to music, such as sound recording and reproduction, are surveyed.
C. Blair

History/Literature

21.621 Western Music to 1750

Prereq.: Permission of Instructor
U (1)
3-0-6

European art music from its foundation in antiquity through the Christian Middle Ages, the Italian Renaissance, and the Baroque. Written assignments offer the opportunity to write about the music itself and about topics in the history of musical style.
L. Lindgren

21.622 Western Music after 1750

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

A chronological survey of European art music during the Classic, Romantic, and Modern periods. Compositions analyzed in detail, and placed within their historical context. Most written assignments analyze musical works, so score-reading ability is helpful.
L. Lindgren

21.623 Music of the Near and Far East (Revised Content)

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Survey of the many musical forms and functions which evolved in the traditional practices of people of the Eastern World. It deals with music of the Jews, the Islamic world, India, Tibet, China, Korea, and Japan. The three aspects selected to cut across the cultural boundaries are: 1) Music and Religion, 2) Music of the Court and Theater, and 3) Folk Music. Lectures and video tape demonstrations accompany the reading and listening assignments.
S. Erdely

21.625 Vivaldi, Bach, and Handel

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Representative works of three great composers who wrote at the culmination of the Baroque era in music are examined and related both to compositions by their precursors and societal and intellectual developments of the time in Italy, Germany, and England. Score-reading ability helpful.
L. Lindgren

21.626 Haydn, Mozart, and Beethoven

Prereq.: Permission of Instructor
U (2)
3-0-6

A study of musical life during the second half of the 18th and early 19th centuries through representative works of these composers. Emphasis on harmonic, melodic, and structural development in relationship to intellectual, artistic, and social patterns of the period. Required reading and listening assignments.
L. Lindgren

21.627 Schubert to Mahler

Prereq.: Permission of Instructor
U (1) **Next offered 1989-90**
3-0-6

A survey of the principal developments in musical style during the 19th century. Works for consideration in weekly class discussions drawn from the music of Beethoven, Schubert, Schumann, Brahms, Berlioz, Chopin, Liszt, Wagner, Verdi, Richard Strauss, and Mahler. Required reading and listening assignments.
Staff

21.628 Twentieth-Century Music

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

A survey of major works of the 20th century, beginning with Schoenberg, Stravinsky, Bartok, and Ives; continuing with Varese, Webern, Hindemith, Copland, Sessions, Britten, Prokofiev, and Dallapiccola, and closing with some recent music.
P. Child

21.631 Symphonic Music

Prereq.: Permission of Instructor
U (1) HUM-D
3-0-9

The evolution of symphonic forms from the Baroque to the 20th century. Special attention focused on the works of Haydn, Mozart, and Beethoven. Recordings and opportunities to hear live performances augmented by class discussion.
S. Erdely

21.633 Operas of Mozart, Verdi, Wagner

Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

Focus on the ways in which music has interpreted and enriched three dramatic texts set by each composer. A framework is established by a survey of three Baroque operas at the beginning of the term, and three 20th-century works at the end. Available videotape performances serve as the basis for listening assignments and analytical papers.
L. E. Lindgren

21.634 Film Music

Prereq.: —
U (2)
3-0-6

A chronological survey of styles and functions of music in American and European films. The first half covers 19th-century forerunners, the silent film, and music in synchronized sound films up to 1950. The second half focuses on innovative uses of music from the 1950s up to the present. Related topics include: theories of film music, specialized genres (musical, documentaries, animated films), and the impact of video. Listening, reading, and viewing assignments serve as the basis for papers and class discussion.
M. Marks

21.635 American Music

Prereq.: Permission of Instructor
U (2)
3-0-6

First half focuses on the role of music in North American society (especially the Boston area) during the 18th and 19th centuries. Second half surveys the music of 20th-century North America, including "classical," Broadway show, film, and popular music, but excluding jazz.
L. E. Lindgren

21.636 Jazz

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Historical survey beginning with early jazz, Joplin, Morton, Armstrong, Smith; continuing with a study of the Ellington, Basie, Goodman, and Herman bands; and concluding with a number of individual performers — Parker, Rollins, Monk, Holliday, Gillespie, Mingus, Davis — and some recent developments in writing and playing. Examination of jazz source music: early blues, spirituals, show tunes. Some investigation of jazz-derived musics: post-World War II pop and rock.
M. Harvey

Theory/Composition

21.641 Harmony and Counterpoint I

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Basic writing skills in music of the common-practice period (Bach to Brahms). Work includes regular written assignments leading to the composition of short pieces, analyzing representative works from the literature, keyboard laboratory, and sight-singing choir. It is recommended that entering students have some concert music listening or playing background and some familiarity with reading printed music.
E. Cohen, P. Child, T. Lee

21.642 Harmony and Counterpoint II

Prereq.: 21.641
U (1, 2)
3-3-6

A continuation of Harmony and Counterpoint I, including chromatic harmony and modulation, more elaborate contrapuntal textures, keyboard laboratory, and sight-singing choir.
E. Cohen

21.643 Writing in Tonal Forms

Prereq.: 21.642
U (1)
3-0-6

Written and analytic exercises based on 19th-century small forms and harmonic practice found in music such as Schubert Ländler and songs, Schumann small piano pieces and songs, and Chopin preludes and mazurkas.
P. Child

21.644 Advanced Writing

Prereq.: 21.643
G (2)
3-0-6

A study of compositional procedures during the early years of the 20th century. Emphasis on written and analytical exercises of music which make use of elementary set operations as found in selected Debussy preludes and Bartok mikrokosmos, and the early atonal works of Schoenberg and Webern. Students expected to attend the weekly graduate seminar in composition.
E. Cohen

21.645 Advanced Musical Analysis

Prereq.: 21.641
U (2)
3-0-6

21.646 Advanced Musical Analysis

Prereq.: 21.641
G (2)
3-0-6

An enrichment of musical perspective of particular value to performers. Study of various concepts of musical structure and organization and of the role of structure in musical perception, coherence, and performance. Factors that provide compositional unity and uniqueness, particularly the role of time in musical structure (tempo, rhythm, meter), also examined extensively. Study of scores, listening to recordings, readings, and a paper constitute out-of-class work.
D. M. Epstein

21.648 Jazz Harmony and Arranging

Prereq.: 21.602, 21.636
U (2)
3-0-6

Basic harmony for students interested in acquiring practical skill in nonclassical music; also includes required listening, mainly jazz, as background for the written work. Serves as preparation for more advanced work in jazz and rock arranging and in the composition of popular songs. Permission of instructor required.
M. Harvey

Performance

Each of the following subjects earns six units. A total of 12 units is needed for a subject to count toward Institute Requirements in Humanities, Arts, and Social Sciences, by petition to COC.

21.651 Vocal Repertoire and Performance

Prereq.: —
U (1, 2)
2-4-0

21.652 Vocal Repertoire and Performance

Prereq.: —
G (1, 2)
2-4-0

For the young singer interested in the study and performance of the vocal literature with special attention to diction and vocal technique. Topics each semester include German Lieder or French melodies, as well as songs in the English language. Participation in MIT Chamber Chorus is required (no extra credit). Admission by audition. May be repeated for additional credit.
J. Oliver

21.653 MIT Chamber Chorus

Prereq.: —
U (1, 2)
4-0-2

Rehearsal and performance of choral repertoire for small chorus, involving literature from the Renaissance to contemporary periods. Membership limited to 32 students by audition. May be repeated for additional credit.
J. Oliver

21.655 Chamber Music Society

Prereq.: —
U (1, 2)
0-3-3

Study of chamber music literature through analysis, rehearsal, and performance. Weekly seminars and coaching. Open to string, piano, brass, and woodwind players, and MIT students of early music in the Wellesley Collegium. By audition. May be repeated for additional credit.
M. A. Thompson

21.656 MIT Concert Band

Prereq. —
U (1, 2)
0-3-3

An option available to members of the MIT Concert Band who are committed to the analysis of works in rehearsal and to the study of concert band performance issues. Such analysis and study is made in sessions before or after regular rehearsals and by means of attendance at performances given by other concert bands. May be repeated for additional credit.
J. Corley

21.657 MIT Symphony

Prereq.: —
U (1, 2)
0-3-3

An option available to members of the MIT Symphony Orchestra. Rehearsals prepare works for concerts and recordings. Analyses of musical style, structure, and performance practice are integrated into rehearsals as a means of enriching musical conception and the approach to performance. Likewise, additional scores of particular or structural or stylistic interest are read whenever time permits. May be repeated for additional credit.
D. M. Epstein

21.658 Advanced Music Performance

Prereq.: —
U (1, 2)
1-2-3

21.659 Advanced Music Performance

Prereq.: —
G (1, 2)
1-2-3

Open by audition to students who demonstrate considerable technical and musical skills and who wish to develop them through intensive private study. Students must take a weekly lesson, attend a regular performance seminar, and participate without credit in an MIT ensemble. Full-year commitment required. May be repeated for credit. Information about lesson fees, scholarships, and auditions available in Music Section Office.
M. A. Thompson

Seminars/Tutorials

21.671J Digital Audio Processing (A)

(Same subject as 4.921J)
Prereq.: Permission of Instructor
G (1)
3-6-3

See description under subject 4.921J.
B. Vercoe

21.672J Writing for Computer Performance (A)

(Same subject as 4.922J)
Prereq.: 21.671J
G (2)
3-6-3

See description under subject 4.922J.
B. Vercoe

21.682 Computer Music Composition (A)

Prereq.: 21.672J
G (1, 2)
3-6-3

Directed composition of larger forms of original writing using computer-processed sound, to be performed either alone or with voices and/or instruments. Includes a weekly seminar in composition for the examination of major works from 20th-century music literature and for the presentation and discussion of student works in progress. Students expected to produce at least one substantive work to be performed in public by the end of the term. Open to qualified undergraduates. May be repeated for credit.
B. L. Vercoe

21.685J Musical Aesthetics and Media Technology (A)

(Same subject as 4.925J)
Prereq.: Permission of Instructor
G (1)
3-3-3

See description under subject 4.925J.
T. Machover

21.686J Projects in Media and Music (A)

(Same subject as 4.926J)
Prereq.: Permission of Instructor
G (2)
3-3-3

See description under subject 4.926J.
T. Machover

21.691, 21.692 Special Topics in Music

Prereq.: Any two subjects in Music
U (1, 2)
Arr.

Open to qualified students who wish to pursue special studies or projects with members of the Music Section. Students electing this subject must secure the approval of the chairman of the Music Section. Humanities credit for Special Topics subjects awarded only by individual petitions to the Committee on Curricula. Normal maximum is 6 units; to count toward Humanities Requirement, 9 units are required. Exceptional 9-unit projects occasionally approved. Consult Music Section Office.

21.693, 21.694 Advanced Topics in Music (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Opportunity for advanced study of musical topics not covered by the regular subject listings. Includes experimental subjects offered by permanent and visiting faculty. Students seeking an individual program of study with a particular faculty member must also obtain the approval of the chairman of the Music Section. Consult Music Section Office.

21.695-21.699 Research in Music

Prereq.: 21.671
G (1, 2, S)
Arr.

Directed research on problems occurring in the production, perception, or cognition of music, aided by the techniques and discipline of science and engineering. Individual or group work. Available also to research assistants for non-thesis work. May be repeated for credit with permission. Coordinator: B. L. Vercoe.

Theatre and Dance

Subjects in Theatre and Dance offer an opportunity for practical experience in the production and performance of plays and dance. For subjects dealing with literature of the theatre see 21.005, 21.009, 21.021, 21.022, 21.086, 21.173 in Literature; and 21.223, 21.237, 21.306 in Foreign Languages and Literatures. These subjects, plus the ones described below, constitute the Drama Program, a field of concentration (see Chapter VII).

21.700 Introduction to Acting

Prereq.: —
U (1)
3-0-6

An introduction to the principles of acting through theatre games, exercises, textual analysis, and rehearsal techniques. Practical work is designed to improve sensitivity to language, emotional and physical expression, sensory perception, and imaginative power. Classwork includes lectures, demonstrations, play seminars, and acting workshops. Dramatic material is taken from Shakespeare and Arthur Miller. Preference is given to freshmen and sophomores.
D. E. Campbell

21.701 Acting Shakespeare

Prereq.: 21.700
U (2)
3-0-6

A second-level acting course that seeks to reinforce and develop basic principles established in Acting I. Students are taught how to use these principles in the study and practical exploration of Shakespeare. Primary emphasis is on language and how to decipher rhythm and image codes in the verse. Two plays are examined from an actor's point of view and practical work includes the preparation of a scene and two monologues.
D. E. Campbell

21.702 Theatre Arts: Elementary Stagecraft and Production Studies (Revised Content)

Prereq.: —
U (1, 2)
3-0-6

Team-taught tutorial in theatre arts covers lighting and set design for drama and dance, costuming, makeup, properties, sound, elements of acting, and directing. Includes regular meetings with local area professionals in theatre and dance. Students undertake two projects in the semester productions of Dramashop, Shakespeare Ensemble, and/or Dance Workshop. Written reports, interpretation of the plays, and reviews of outside performances supplement the practical theatre work.
R. Scanlan, W. Fregosi, E. Darna

21.703 Performance Workshop in Drama

Prereq.: —
U (2)
3-0-6

A seminar focusing on script interpretation, directing technique, and production planning. Readings in Aristotelian dramatic theory precede detailed study of several plays to acquire facility in analyzing dramatic form and discerning the underlying action pattern that gives shape to a play. Class discussion and directed scene work lead to the detailed planning of a specific theatre production. Readings in dramatic theory, oral class presentations, and one major paper required.
R. N. Scanlan

21.704 Perspectives on Dance (Revised Content)

Prereq.: —
U (1, 2)
1-3-2

Dance through history and practice. Study of the development of various forms, including primitive dance and classical ballet. Relation of 20th-century dance to other arts. Readings and assignments. Also regular practical activity in modern dance technique or composition/improvisation according to experience. *B. Soll*

21.705 Dance Workshop: Technique and Composition (New)

Prereq.: 21.704
U (1, 2)
0-5-1

Directed activity (at least three times per week) in dance composition/improvisation and in modern dance technique. Participants grouped by experience. Students also required to participate as dancers or choreographers in end of term concerts. May be repeated for additional credit.
B. Soll

21.706 Special Topics in Drama

(21.705)
Prereq.: —
U (1, 2)
Arr.

Designed to allow students to pursue topics of individual interest under the supervision of a member of the Program in Theatre and Dance. Requires the approval of the Dean of the School of Humanities and Social Science. Normal credit maximum: 6 units. Students who wish to use Special Topics for Humanities credit must register for 9 units **and** file a petition, approved by the Dean of the School of Humanities and Social Science, with the Committee on Curricula.
R. N. Scanlan

21.707 Special Topics in Dance

Prereq.: —
U (1, 2)
Arr.

Designed to allow students to pursue topics of individual interest under the supervision of a member of the Program in Theatre and Dance. Requires the approval of the Dean of the School of Humanities and Social Science. Normal credit maximum: 6 units. Students who wish to use Special Topics for Humanities credit must register for 9 units **and** file a petition, approved by the Dean of the School of Humanities and Social Science, with the Committee on Curricula.
B. Soll

The Writing Program

The subjects listed below are grouped in the three major areas of The Writing Program: 1) Exposition and Rhetoric; 2) Creative Writing; and 3) Science and Technical Writing. Within each area, introductory, intermediate, and Advanced subjects are offered. Introductory subjects are designed for students with little or no experience in writing; intermediate subjects are designed for students who have mastered the elements of sentence and paragraph structure; Advanced subjects are designed for experienced writers who wish to develop greater competence in one or more special forms of writing.

Exposition and Rhetoric

Introductory

21.730 Expository Writing

Prereq.: —
U (1, 2)
3-0-9

For students who wish to write correct, clear, and effective prose. Attention to constructing effective sentences and paragraphs. Weekly writing assignments. Students' writing is discussed frequently in class. Readings include essays that exhibit a wide range of rhetorical techniques. Satisfies Phase I of the Writing Requirement.
H. Ritvo, Staff

21.731 Writing and Experience

Prereq.: —
U (1, 2)
3-0-9

Students study the mechanisms by which fiction writers, essayists, and poets transform their experience into scenes, voices, and arguments. Attention given to sentence mechanics, paragraphing, punctuation, and word choice. In weekly workshops, students present their writing to members of the group, and extensive revising is required. Satisfies Phase I of the Writing Requirement.
E. E. Chodakowska, Staff

21.732 Introduction to Technical Communication

Prereq.: —
U (1, 2)
3-0-9

Students intensively review the elements of sentence and paragraph structure; special problems in organizing and condensing technical information; and strategies for writing technical descriptions, definitions, classifications, and analyses. Other topics include writing to different audiences and preparing brief proposals, lab reports, and graphics. Several short writing assignments, frequent revisions, and two short oral presentations required. Satisfies Phase I of the Writing Requirement.
J. Paradis, Staff

21.734 Style

Prereq.: —
U (1)
3-0-6

Intensive practice in writing clear prose. Frequent short themes focus on daily experience. Class discussions emphasize style. Reading consists of short published pieces, to be analyzed in class, and student papers. Weekly writing includes a theme, commentary on work by classmates, and a revision.
T. Simmons

Intermediate

21.735 Writing and Reading the Essay

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Exploration of formal and informal modes of writing nonfiction prose. Extensive practice in composition, revision, and editing. Reading in the literature of the essay from the Renaissance to the present, with an emphasis on modern writers. Classes alternate between discussion of published readings and workshops on student work. Individual conferences.
H. Ritvo, Staff

21.736 Writing Across the Cultures (New)

Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

Students use writing to explore the relations among three major intellectual cultures in contemporary society: scientific, engineering, and humanistic. A central purpose of the class is to use writing to create connections among these cultures. Students read essays, biographies, and autobiographies and write five essays. Some lecture, mostly discussion and round-table critique of student papers.
M. La Follette, R. Williams

21.738 Words

Prereq.: —
U (1)
3-0-6

Designed to increase appreciation of the verbal resources of English and improve skill in exploiting them. Considers such topics as the historical roots of the modern vocabulary, specialized and technical vocabularies, socially loaded language, the connection between word choice and tone, words as symbols. Regular written assignments stress the way that ideas are shaped by words.
H. Ritvo

21.740 Writing Autobiography and Biography

Prereq.: —
U (2)
3-0-9

Writing autobiography is used as a vehicle for improving style and studying the nuances of the language. Literary works are read with an emphasis on different forms of autobiography (essay, fiction, etc.). Class examines various stages of life, significant transitions, personal struggles, and memories translated into narrative prose, and discusses 1) what it means for autobiographer and biographer to develop a personal voice; and 2) the problems of reality and fiction in autobiography and biography. Students write in either or in both modes.
C. Wolff

21.742 Writing About Racial Issues (New)

Prereq.: —
U (2)
3-0-9

The issue of race has preoccupied many writers both here and in Europe. Students read Faulkner, Toni Morrison, James Baldwin, Bernard Malamud, among others, and write about racial and ethnic issues either in the form of biography or fiction. Students may write short or longer pieces. Their work is read and discussed in class and, if necessary, revised, incorporating comments and criticism elicited in discussion.
E. E. Chodakowska

Advanced

21.745 Advanced Essay Workshop

Prereq. : Permission of Instructor
U (2)
3-0-9

For students with experience in writing nonfictional prose. Advanced study of rhetorical strategies and techniques of prose style. Considerable writing and revision required. In addition to analyzing the work of class members, students read and discuss the work of distinguished essayists chosen to represent a range of prose styles, subjects, and biographical patterns.
H. Ritvo

Creative Writing

Introductory

See subject 21.731.

Intermediate

21.755 Writing and Reading Short Stories

Prereq.: —
U (1, 2) HUM-D
3-0-9

Introduction to the short story. Students write stories and short descriptive sketches. Readings from European and American stories from the 18th, 19th, and 20th centuries. Class discussion of students' writing and of the assigned stories in their historical and social contexts.
I. Karmel, S. Strang

21.757 Fiction Workshop

Prereq.: 21.755
U (1, 2)
3-0-6

For students interested in writing fiction. May be taken as a prerequisite to the Advanced Fiction Workshop, but its main purpose is to encourage students to experiment with various techniques of fiction writing. Weekly reading and writing assignments; class discussion of students' writing and work of professional writers.
I. Karmel

21.758 Genre Fiction Workshop

Prereq.: One intermediate fiction writing subject
or Permission of Instructor
U (1)
3-0-9

Students write stories in such genres as science fiction, fantasy, horror, crime fiction, "international intrigue," western fiction, and historical fiction. Students read a range of authors from Edgar Allen Poe, to Dashiell Hammett, to Zane Grey. The first few class meetings consist of introductory lectures and discussion, but most of the class is devoted to round-table criticism of the students' work. Enrollment limited to 15 students.
J. Haldeman

21.759 Writing Science Fiction

Prereq.: —
U (1)
3-0-6

Students write and read science fiction and analyze and discuss stories written for the class. For the first eight weeks, readings in contemporary science fiction accompany lectures and formal writing assignments intended to illuminate various aspects of writing craft as well as the particular problems of writing science fiction. The rest of the term is given to round-table workshops on students' stories.
J. Haldeman

21.760 Writing and Reading Poems

Prereq.: —
U (1, 2) HUM-D
3-0-9

Examination of the formal structural and textual variety in poetry. Extensive practice in the making of poems and the analysis of both students' manuscripts and texts from 16th- through 20th-century literature. Attempts to make relevant the traditional elements of poetry and their contemporary alternatives. Weekly writing assignments, including some exercises in prosody.
T. Simmons

21.762 Poetry Workshop

Prereq.: —
U (2)
3-0-6

For students with some previous experience in poetry writing. Frequent assignments stress use of language, diction, word choice, line breaks, imagery, mood, and tone. Considers the functions of memory, imagination, dreams, poetic impulses. Throughout the semester, students examine the work of published poets. Revision stressed.
Staff

Advanced

21.770 Advanced Fiction Workshop

Prereq.: Permission of Instructor
U (1, 2)
3-0-6

For students with some experience in writing fiction. Concentrates on the ways an author manipulates his or her audience in the creation of a particular vision of reality. Studies style; point of view; distinctions of time and space; stream-of-consciousness; all the strategies for making a work of art. Outside readings assigned on an individual basis.
E. E. Chodakowska

21.771 Advanced Poetry Workshop

Prereq.: Permission of Instructor
U (2)
3-0-6

For students experienced in writing poems. Regular reading of published contemporary poets and weekly submission of manuscripts for class review and criticism. Expects students to do a substantial amount of rewriting and revision. Classwork supplemented with individual conferences.
Staff

21.773 Writing Longer Fiction

Prereq.: Permission of Instructor
U (1)
3-0-6

For students with some experience in writing fiction who wish to experiment with its longer forms (primarily the novella). The possibilities and techniques of longer fiction studied in examples of modern European and American authors (i.e., Tolstoy, Conrad, Kafka, Bellow). Class discussions of students' own work with emphasis on revision.
I. Karmel

Science and Technical Writing

Introductory

See subject 21.732.

Intermediate

21.777 The Scientific Essay

Prereq.: —
U (1, 2) HUM-D
3-0-9

Students explore prominent writing about science and technology from the Renaissance to the present. They examine the style, purpose, and context of historically important papers and essays. Discussion includes the role of communication in science, the rise of scientific journals, and ethical issues in scientific writing. Readings include works by Newton, Darwin, Einstein, and contemporary authors. Several short assignments and a longer essay on a general or semitechnical subject required.
R. Williams, Staff

21.780 Scientific and Engineering Writing

Prereq.: —
U (1, 2)
2-0-7

Introduction to the forms, functions, and style of technical documents: weekly sessions include grammar and composition reviews, editing workshops, and discussion of the scientific publication process. Short assignments — including abstracts, proposals, progress reports, and memos — build toward a written term paper and oral presentation on a technical or semitechnical subject. Students should have completed, or be working on, research that they can write about.
M. LaFollette, J. Paradis, Staff

21.782 Science Journalism

Prereq.: —
U (1, 2)
3-0-6

A practical introduction to the craft of science journalism. Class discussion examines important issues in communicating technical information to the public, such as the relationship among science, technology, and the media. Presentations by professional science journalists are featured. Students write weekly exercises, some of which are submitted for publication. Writing competence required.
M. LaFollette

Advanced

21.783 Science and Technical Writing Workshop

Prereq.: 21.782
U (1, 2)
3-0-9

Introduces students to the process of planning, writing, editing, and producing in-house and professional publications. Discussions and demonstrations cover the techniques of document design and production, with emphasis on current technologies used to prepare in-house documents. The problem of matching form and style to audience receives special attention. Students make a site visit to observe a large in-house production facility. In addition to individual work, students collaborate to plan, write, and produce a major document.
M. LaFollette

21.790 Naturalist Writing

Prereq.: —
U (1)
3-0-9

Students write about nature in a variety of ways, aesthetic and technical, in essays and in technical documents. They study the responses to nature of 19th- and 20th-century naturalists, such as Audubon, Darwin, Thoreau, Lorenz, Carson, and Goodall. They examine local publications and films of nature societies in New England, the Northwest, and the South, as well as such modern forms as the environmental impact statement and the technical report. Several short and two longer writing assignments on general and semitechnical subjects.
J. Paradis

21.792 Science and Technical Writing Internship

Prereq.: 21.780 or 21.782
U (2)
3-0-9

Part-time internships in Boston-area media and industries are arranged for students wishing to develop professional writing and publishing skills. Students planning to take this subject must contact the instructor by November of the previous term.
J. Paradis

21.793 Advanced Workshop in Scientific and Engineering Writing

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

Offers graduate students who have writing projects under way an intensive review and step-by-step practice in technical writing. Examines major types of technical documents and reviews organization, grammar, style, format, graphics, and the scientific publishing process. Writing and revising assignments are adapted to the preparation of one or two major documents.
K. R. Manning, Staff

21.798, 21.799 Special Topics in Writing

Prereq.: —
U (1, 2)
Arr.

Primarily for students pursuing writing advanced projects with the assistance of a member of the Writing Program. Students electing this subject must secure the approval of the Director of the Writing Program and its Committee on Curriculum. Normal maximum is 6 units; to count toward Humanities Requirement, 9 units are required. Exceptional 9 unit projects occasionally approved.
K. R. Manning

Interdisciplinary Subjects

21.914 Sports and Physical Training

Prereq.: Permission of Instructor
U (2)
3-0-6

Social function of sports and physical training in modern times, especially in the United States. Readings, films, discussions. Group research projects. Limited enrollment.
L. Kampf

21.915 Intellectuals and Social Change

Prereq.: Permission of Instructor
U (2) **Next offered 1989-90**
3-0-6

Role and responsibility of individuals who challenge the assumptions of the established political and social order. Discussion of current issues that have given rise to action and protest. Visiting lectures by activists. Questions of individual commitment, and the available alternatives for action. Limited enrollment.
N. A. Chomsky, L. Kampf

21.916 Contemporary Issues in Politics and Ideology

Prereq.: Permission of Instructor
U (2)
3-0-6

Selected topics in international and domestic affairs. Emphasizes their relationship to US political, economic, and ideological institutions. Critical analysis of capitalist ideology. Considers strategies for social change.
N. A. Chomsky

21.917J Current Issues in the Women's Movement

(Same subject as SP 452J)
Prereq.: —
U (2)
3-0-9

This course considers a variety of issues relating to women's lives, both in the public and personal spheres. We begin by looking at the historical background of the current women's movement, then move on to the present. Topics include equality of opportunity, career vs home, women's health, abortion, women in politics, race, and sexual preference. We discuss some of the grass roots organizing around these issues, and visiting activists lead some of the discussions.
L. Kampf, J. Seager

21.930J Ancient Cosmology

(Same subject as STS 007J)
Prereq.: —
U (1)
3-0-6

Evidence for, and astronomical database of, archaic cosmology. Myth, alignments, ritual as prenumerate, technical languages in oral culture. Algebraic, geometric, numerate, musical, biological, socio-juridical models in pre-Socratic philosophy: Anaximander, Pythagoreanism, Heraclitus, Parmenides, Zeno, Empedocles, Democritus, Plato's *Timaeus*, and Aristotle. Collateral readings in modern secondary literature and in works by Von Dechend, Karl Popper, Schroedinger, Collingwood, D'Arcy Thompson, T. S. Kuhn.
H. A. T. O. Reiche

21.991 Special Topics in Interdisciplinary Studies

Prereq.: Any two subjects in Humanities
U (1)
Arr.

21.992 Special Topics in Interdisciplinary Studies

Prereq.: Any two subjects in Humanities
U (2)
Arr.

Special topics involving interdisciplinary study sponsored by members of the Department of Humanities or Institute faculty. Subjects vary from year to year. Must have the approval of the Humanities Undergraduate Office. Humanities credit for Special Topics subjects awarded only by individual petitions to the Committee on Curricula. Normal maximum is 6 units; to count toward Humanities Requirement, 9 units are required. Exceptional 9-unit projects occasionally approved.
P. S. Khoury

Please note: Philosophy subjects are listed under Course 24, Linguistics and Philosophy.

Subjects in Science, Technology, and Society are listed under that heading in this chapter.

Information about the following programs may be found within the description of the School of Humanities and Social Science in this catalogue:

American Studies
Ancient and Medieval Studies
Drama
Film and Media Studies
Latin American Studies
Psychology
Russian Studies
Women's Studies

Course 22 Nuclear Engineering

Undergraduate Subjects

22.UR Undergraduate Research Opportunities Program

Prereq.: —
U (1, 2) [P/F]
Arr.

The Undergraduate Research Opportunities Program is an excellent way for undergraduate students to become familiar with the Department of Nuclear Engineering. Student research as a UROP project has been conducted in areas of fission reactor studies, utilization of fusion devices, applied radiation research, and biomedical applications. Projects include the study of engineering aspects for both fusion and fission energy sources. UROP Department Coordinator: R. G. Ballinger.

22.002 Management in Engineering

Prereq.: —
U (1)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
D. P. Hoult, H. S. Marcus

22.003 Nuclear War: Threat and Avoidance

Prereq.: —
U (2) HASS
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

22.006 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (2) SD
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
S. Shyam Sunder

22.011 Seminar in Nuclear Engineering

Prereq.: —
U (1)
2-0-4

Surveys the range of topics covered by the Department. Introductory discussion of the basic phenomena of fission and fusion power, and related aspects of reactor design. The many applications of nuclear engineering for research in biology, earth sciences, medicine, and physics are discussed by guest lecturers from the appropriate discipline. A demonstration of the MIT Reactor as a research tool is given.
L. M. Lidsky

22.012 Seminar in Fusion and Plasma Physics

Prereq.: —
U (2)
2-0-4

Lecture and discussion introducing the range of topics covered under the fusion option. Introductory discussion of the economic and ecological motivation for the development of fusion power. Contemporary magnetic confinement schemes, theoretical questions, and engineering considerations are presented by expert guest lecturers. Concurrent work on the physics of the solar and terrestial plasma environments also covered. Tour of Plasma Fusion Center experimental facilities.
K. Molvig

22.013 Applications of Radiation in Science, Technology, and Medicine

Prereq.: —
U (1)
2-0-4

Seminar explores a wide range of topics in radiation effects and uses. Some involve state of the art experimental techniques, others make use of unique laboratory facilities or novel computer simulation programs. Each is a current area of teaching or research for one or more faculty members. Most lectures are accompanied by laboratory demonstrations.
S. Yip, R. G. Ballinger, G. L. Brownell, S-H. Chen, O. K. Harling, K. C. Russell

22.02 Introduction to Applied Nuclear Physics

Prereq.: 8.02, 18.02
U (1) SD
3-0-9

Introduces nuclear physics, emphasizing those aspects that are applied in nuclear engineering. Elementary quantum theory; properties of atomic nuclei; natural and induced radioactivity; cross sections for nuclear reactions; alpha-, beta-, and gamma-decay. Nuclear models: shell-model, liquid-drop model, nuclear fission. Slowing down and diffusion of neutrons. Neutron-induced chain reactions. Thermonuclear reactions and the possibility of energy from nuclear fusion. Introduces radiation dosimetry.
N. C. Rasmussen

22.021 Nuclear Reactor Physics

Prereq.: 22.02, 18.03
U (1, 2)
4-0-8

Introduces fission reactor physics. Covers reactions induced by neutrons, nuclear fission, slowing down of neutrons in infinite media, diffusion theory, the few-group approximation, and point kinetics. Emphasizes the nuclear physics bases of reactor design and their relationship to reactor engineering problems. Three lecture hours per week meeting concurrently with 22.211, plus a separate recitation; assignments and quizzes are different from those in 22.211.
A. F. Henry, L. M. Lidsky

22.03 Engineering Design of Nuclear Power Systems

Prereq.: —
U (1) SD
3-0-9

Introduces nuclear engineering as applied to power plant design: Basic principles of nuclear physics, reactor physics, and environmental health physics; engineering and heat-transfer principles. Description of various reactor types (LWR, LMFBR, etc.). Emphasizes reliability and reactor safety methods for improving design and operation of future reactors.
M. W. Golay

22.031 Engineering of Nuclear Reactors

Prereq.: 2.01, 2.51
U (1, 2)
3-0-9

Engineering principles of nuclear reactors, emphasizing power reactors. Power plant thermodynamics, reactor heat generation and removal (single-phase as well as two-phase coolant flow and heat transfer), and structural mechanics. Engineering considerations in reactor design. Meets with 22.312, but examinations differ.
J. E. Meyer, M. W. Golay

22.033 Nuclear Systems Design Project

Prereq.: 22.021, 22.031
U (2)
2-6-4

Group design project involving integration of reactor physics, control, heat transfer, safety, materials, power production, fuel-cycle management, environmental impact, and economic optimization. Provides the student with the opportunity to synthesize knowledge acquired in other subjects and apply this knowledge to practical problems of interest in the reactor design field. Meets with 22.33, but assignments differ.
D. D. Lanning

22.04 Radiation Effects and Uses

Prereq.: —
U (2) SD
2-1-9

Current problems in science, technology, health, and environment that involve radiation effects and their utilization. Medical and industrial applications of radioisotopes. Radiations in research. Laboratory demonstrations of methods and instruments in radiation measurements. Material presented is suitable for students interested in a general appreciation of the physical phenomena and their uses.
Staff

22.061 Fusion Energy I

Prereq.: 8.03, 18.03
U (1)
3-0-9

Basic nuclear physics and plasma physics for controlled fusion. Nuclear physics: fusion cross sections, ignition condition, break-even condition, Lawson criterion, elementary fusion reactor, required plasma parameters. Plasma physics: definition of a plasma, single-particle orbits, Coulomb collisions, fluid model, magnetic fusion configurations, MHD equilibrium and stability, transport and heating. Meets three lecture hours a week with 22.601, but with different assignments and exams.
J. P. Freidberg

22.062 Fusion Energy II

Prereq.: 22.061
U (2)
3-0-9

Basic engineering and technology of controlled thermonuclear reactors. Current confinement devices: tokamaks, mirrors, alternative concepts. Thermonuclear reactors: systems analysis and design of power reactors, ignition experiments, hybrid reactors. Reactor technologies: neutronics, blanket design, magnet design, first wall, materials and activation, heating technology, tritium handling. Present reactor designs: detailed critical review of prototype reference reactor designs. Safety and environment. Meets with 22.602, but with different assignments and exams.
J. P. Freidberg

22.069 Undergraduate Plasma Laboratory

Prereq.: 8.02
U (2) LAB
1-8-3

Basic engineering and scientific principles associated with experimental plasma physics. Investigates vacuum pumping phenomena and gauge operation, normal and superconducting magnetic field coils, microwave interactions with plasmas, laboratory plasma production including electrical breakdown phenomena, Langmuir probe characteristics and spectroscopy. Meets with 22.69, but assignments differ.
I. H. Hutchinson

22.070J Materials for Nuclear Applications

(Same subject as 3.070J)
Prereq.: 3.091
U (2)
3-0-9

Introductory subject for students who are not specializing in nuclear materials. Application and selection of materials for use in nuclear applications. Radiation damage, radiation effects, and their effects on performance of materials in fission and fusion environments. Meets with 22.70J, but assignments differ.
R. G. Ballinger

22.08 Energy

Prereq.: —
U (1)
3-0-9

Energy from a holistic viewpoint. Provision, rational utilization and conservation, environmental effects, policy, and impact on other sectors. Resources, technologies of conversion and utilization. Assessment of both deployed and proposed energy systems and technologies. Includes economic, social, and historic perspectives. Intended for third- and fourth-year students interested in entering the energy field. Meets with 22.81, but some assignments differ.
M. Miller

22.084 Inventions and Patents

Prereq.: 14.02
U (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. H. Rines

22.085 Introduction to Technology and Law

Prereq.: —
U (1) **Next offered 1989-90**
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. D. Nyhart

22.088J Human Factors in Design

(Same subject as 2.18J, 9.39J)
Prereq.: Permission of Instructor
U (2)
3-1-8

See description under subject 2.18J.
D. D. Lanning, T. B. Sheridan, A. Hein

22.09 Principles of Nuclear Radiation Measurement and Protection

Prereq.: 22.02
U (2) LAB
2-6-4

Combines lectures, demonstrations, and experiments. Covers effects of radiation on persons, control of radiation exposure within applicable standards, theory and use of α, β, γ, and n detectors and spectrometers, use of isotopes, radiation shielding, and dosimetry. Includes demonstrations and experiments using the MIT research reactor, accelerators, and power reactors. Meets with graduate subject 22.59, but assignments differ.
N. C. Rasmussen, O. K. Harling

22.091 Special Topics in Nuclear Engineering

Prereq.: —
U (1, 2, S)
Arr.

For undergraduates who wish to conduct a one-term project of theoretical or experimental nature in the field of nuclear engineering, in close cooperation with individual staff members. Topics and hours arranged to fit students' requirements.
J. E. Meyer

22.092 Engineering Internship

Prereq.: —
U (1, 2, S) [P/F]
0-6-0

Provides academic credit for the first two Work Assignments of XXII-A students affiliated with the Engineering Internship Program. Students register for this subject twice. Students must complete both Work Assignments in order to receive the academic credit for this subject. Enrollment limited to students registered in Course XXII-A.
R. G. Ballinger

Graduate Subjects

Nuclear Physics

22.111 Nuclear Physics for Engineers I (A)

Prereq.: 22.02
G (1, 2)
3-0-9

Fundamentals of nuclear physics for engineering students. Basic properties of the nucleus and nuclear radiations. Elementary quantum mechanical calculations of bound-states and barrier transmission probability. Nuclear shell model. Binding energy and nuclear stability. Interactions of charged particles, neutrons, and gamma rays with matter. Radioactive decays. Energetics and general cross-section behavior in nuclear reactions.
K. Molvig, E. P. Gyftopoulos

22.113 Nuclear and Atomic Collision Phenomena (A)

Prereq.: 22.111
G (2)
3-0-9

Principles and applications of quantum theory of nuclear and charged particle collision cross sections. Detailed study of partial wave and phase shift analysis, time-dependent perturbation theory, and Born approximation. Optical model description of nuclear reactions. Atomic stopping power. Thermal neutron inelastic scattering in condensed matter.
S-H. Chen

Nuclear Reactor Physics

22.211 Nuclear Reactor Physics I (A)

Prereq.: 18.076
G (1, 2)
3-0-9

Introduces problems of fission-reactor physics, covering nuclear reactions induced by neutrons, nuclear fission, slowing down of neutrons in infinite media, diffusion theory, the few-group approximation, and point kinetics. Emphasizes the nuclear physical bases of reactor design and their relation to reactor engineering problems.
A. F. Henry, L. M. Lidsky

22.212 Nuclear Reactor Physics II (A)

Prereq.: 22.211
G (2)
3-0-9

Problems relating to the operation of nuclear reactors at power, including few-group and multigroup theory, heterogeneous reactors, control rods, burnable poisons, depletion phenomena, and elementary neutron kinetics. Attention directed to the application of reactor theory to real power reactors.
A. F. Henry

22.213 Nuclear Reactor Physics III (A)

Prereq.: 22.212
G (1)
3-0-9

Current methods for predicting neutron behavior in complex geometrical and material configurations. The transport equation and methods for solving it; systematic derivation of group diffusion theory. Applies homogenization, synthesis, finite element, response matrix techniques and nodal methods to reactor analysis.
A. F. Henry

Nuclear Reactor Engineering

22.311 Energy Engineering Principles

Prereq.: —
G (1)
3-0-9

Fundamentals of engineering thermodynamics, fluid flow, and heat transfer. Applications to various energy sources. Introductory subject for graduate students without previous engineering background.
M. J. Driscoll

22.312 Engineering of Nuclear Reactors (A)

Prereq.: 22.311
G (1, 2)
3-0-9

Engineering principles of nuclear reactors, emphasizing power reactors. Power plant thermodynamics, reactor heat generation and removal (single-phase as well as two-phase coolant flow and heat transfer), and structural mechanics. Engineering considerations in reactor design.
J. E. Meyer, M. W. Golay

22.313 Advanced Engineering of Nuclear Reactors (A)

Prereq.: 22.312
G (2)
3-0-9

Advanced topics in nuclear engineering, emphasizing thermo-fluid dynamic phenomena and analysis methods. Heat transfer and fluid flow in single/parallel channel arrays and loops. Porous body, subchannel and distributed parameter modeling methods for heated rod arrays. Reactor thermal design uncertainty analysis methods.
N. E. Todreas

22.314J Structural Mechanics in Nuclear Power Technology (A)

(Same subject as 1.56J, 2.084J, 3.82J, 13.14J, 16.261J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Structural components in nuclear power plant systems, their functional purposes, operating conditions, and mechanical-structural design requirements. Combines mechanics techniques with models of material behavior to determine adequacy of component design. Effects considered include mechanical loading, hydraulic forces, elevated temperatures, neutron irradiation, and seismic effects.
M. S. Kazimi, O. Buyukozturk

22.32 Nuclear Power Reactors (A)

Prereq.: 22.211, 22.312
G (2)
3-0-9

Describes engineering and physics aspects of current nuclear power reactors. Discusses design details, including requirements for safety of light- and heavy-water reactors, high-temperature gas-cooled reactors, liquid-metal cooled fast reactors, and other reactor concepts. Compares reactor characteristics both in class and by individual student projects. Discusses development problems and assesses potential for future improvements.
J. E. Meyer

22.33 Nuclear Engineering Design (A)

Prereq.: 22.212, 22.312
G (2)
2-6-4

Group design project involving integration of reactor physics, control, heat transfer, safety, materials, power production, fuel-cycle management, environmental impact, and economic optimization. Provides student with opportunity to synthesize knowledge acquired in other subjects and apply this knowledge to practical problems of interest in the reactor design field. Meets with 22.033, but assignments differ.
D. D. Lanning

22.341 Nuclear Energy Economics and Policy Analysis (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

A comprehensive assessment of the economic, environmental, political, and social aspects of nuclear power generation and the nuclear fuel cycle. Quantitative applications of the principles of engineering economics; comparison of alternatives, using discounted cash flow methods. Technology assessment/policy analysis of institutional alternatives for R&D, management, and regulation; includes nuclear power plant licensing, nuclear waste management, and nuclear power and weapons proliferation. Open to qualified undergraduates. Term paper required.
R. K. Lester, M. Miller

22.35 Nuclear Fuel Management (A)

Prereq.: 22.211
G (2) **Not to be offered 1989-90**
3-0-9

Principles of physics and engineering that govern and constrain the configuration, arrangement, and time-dependent behavior of fuel for nuclear reactors. Emphasizes in-core and front-end aspects, and light-water reactor applications. Economic optimization of fuel cycles, fuel design, and assembly management, considering both long-term strategic goals and short-term tactics.
M. J. Driscoll

22.36J Two-Phase Flow and Boiling Heat Transfer (A)

(Same subject as 2.57J)
Prereq.: 22.312
G (2) **Next offered 1989-90**
3-0-9

Phase change in bulk stagnant systems. Kinematics and dynamics of adiabatic two-phase flow. Dynamics and thermodynamics of forced-convection two-phase flow with boiling and/or evaporation. Thermal and hydrodynamic stability of two-phase flows. Associated topics, such as condensation and atomization. Both water and liquid metal applications considered under each topic where data exists.
M. S. Kazimi, P. Griffith, W. M. Rohsenow

22.37 Environmental Impacts of Electricity (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Assesses the various environmental impacts of producing thermal and electric power with currently available technology. Compares impacts throughout both the fossil and nuclear fuel cycles. Topics include fuel resources and extraction, power station effluents, waste heat disposal, reactor safety, and radioactive waste disposal.
M. W. Golay

22.38 Reliability Analysis Methods (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Principles of the methods of reliability analyses, including fault trees, decision trees, and reliability block diagrams. Discusses the techniques for developing the logic diagrams for reliability assessment, the mathematical techniques for analyzing them, and statistical analysis of required experience data. Discusses practical examples of their application to the risk assessment of nuclear power reactors and other industrial operations. Open to qualified undergraduates.
N. O. Siu

22.39 Nuclear Reactor Operations and Safety (A)

Prereq.: 22.211, 22.311
G (1) **Not to be offered 1989-90**
Arr.

Principles of operating nuclear reactor systems in a safe and effective manner. Emphasizes light-water reactor systems with transient response studies, including degraded core recognition and mitigation. Consequence analysis and risk assessment. Lessons from past accident experience. NRC licensing and regulations. Demonstrations: operation of the MIT research reactor; use of a PWR concept simulator. Optional laboratory section involves a project at the Nuclear Reactor Laboratory.
D. D. Lanning

22.40J Advanced Reliability Analysis and Risk Assessment (A)

(Same subject as 13.63J)
Prereq.: 22.38, 22.82
G (2) **Not to be offered 1989-90**
3-0-9

Extended application and use of reliability and probabilistic risk analysis methods. Methods for common mode failure analysis and treatment of dependencies. Bayesian statistics applied to systems reliability and safety problems. Error/ sensitivity analysis. Time-dependent reliability analysis, Markov models, systems availability, and systems performance. Replacement and maintenance strategy development. Case studies of safety analyses in nuclear and nonnuclear areas.
N. O. Siu

Numerical and Mathematical Methods

22.41 Numerical Methods of Radiation Transport (A)

Prereq.: 18.076, 22.212
G (2) **Next offered 1989-90**
3-0-9

Mathematical methods for the solution of neutron/photon transport problems: detailed development of discrete ordinates and Monte Carlo methods for applications in radiation shielding, reactor analysis, and biomedical dosimetry. Discusses iteration techniques for solution of coupled difference equations. Group projects on solving original transport problems by design and implementation of computer codes.
S. Yip

22.42 Numerical Methods in Engineering Analysis (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Applications of digital computers to the solution of engineering problems. Reviews specific mathematical techniques (linear algebra, interpolation, finite-difference equations). Numerical solution of ordinary differential equations. Fundamentals of consistency, convergence, stability, and accuracy. Numerical solution of elliptic, parabolic, and hyperbolic partial differential equations. Special topics from nuclear reactor physics, heat transfer, and fluid dynamics.
K. F. Hansen

22.43 Advanced Numerical Methods in Engineering Analysis (A)

Prereq.: 22.42
G (1) **Not to be offered 1989-90**
3-0-9

Advanced computational methods. Emphasizes solution of multidimensional problems. Modern iterative techniques. Solution of nonlinear equations. Numerical methods in two-phase flow. Finite-element methods with applications to incompressible and compressible flows. Introduction to numerical turbulence modeling. Additional special topics, varying with interests of the class and covering latest developments. Assignments and group projects requiring use of computer. Permission of instructor required for students without 22.42 background.
K. F. Hansen

Radiation Interactions and Applications

22.51 Radiation Interactions and Applications (A)

Prereq.: 8.05
G (1)
3-0-9

Basic principles of interaction of electromagnetic radiation, thermal neutrons, and charged particles with matter. Introduces classical electrodynamics, quantum theory of radiation field, time-dependent perturbation theory, transition probabilities and cross sections describing interaction of various radiations with atomic systems. Applications include theory of nuclear magnetic resonance; Rayleigh, Raman, and Compton scattering; photoelectric effect; and use of thermal neutron scattering as a tool in condensed matter research.
S-H. Chen

22.53 Statistical Processes and Atomistic Simulations (A)

Prereq.: —
G (1)
3-0-9

Statistical mechanics principles of equilibrium and time-dependent properties of condensed states of matter. Phase-space distributions, time correlations functions, kinetic equations. Free energy calculations. Stochastic processes. Continuum and molecular models for transport phenomena and phase transitions. Methods and applications of molecular dynamics and Monte Carlo simulations in statistical physics and materials science.
S. Yip

22.55J Biological and Medical Applications of Radiation and Radioisotopes (A)

(Same subject as HST 560J)
Prereq.: 8.272 or 22.111
G (2)
4-0-8

Principles of radiation production and interactions. Radiation dosimetry, emphasizing applications and health hazards. Shielding of beta, gamma, and neutron radiation from isotope and machine sources. Detection and spectroscopy of beta, gamma, and neutron radiation. Neutron activation analysis. Production of radioisotopes and radiopharmaceuticals. Principles of nuclear medicine. Requires a comprehensive term paper and presentation.
Staff

22.56J Principles of Medical Imaging (A)

(Same subject as 2.761J, HST 561J)
Prereq.: Permission of Instructor
G (1)
4-0-8

Principles of medical imaging, including X-ray, nuclear medicine, ultrasound, NMR, emission- and transmission- computed tomography, and other modalities. Two-dimensional and three-dimensional imaging techniques and displays. Fundamentals of image formation, physiology of image perception, physics of radiation and ultrasound interaction and detection, and physics of NMR. Quantification of images and reconstruction algorithms. A comprehensive term paper required.
V. Wedeen, P. P. Lele

22.561J Magnetic Resonance — Analytic, Biochemical, and Imaging Techniques (A)

(Same subject as HST 584J)
Prereq.: Permission of Instructor
G (2)
3-0-12

See description under subject HST 584J.
B. Rosen

22.57J Radiation Biophysics (A)

(Same subject as HST 568J)
Prereq.: 22.111
G (1)
4-0-8

Effects of ionizing radiation, ultraviolet radiation, and heat on biological materials, cells, and tissues. Examines *in vivo* and *in vitro* mammalian systems, and explores mathematical models for cell survival, emphasizing prediction. Microstructural damage to cell components such as membranes, organelles, enzymes, and DNA studied. Radiation syndromes in man, mutagenesis, and carcinogenesis also investigated.
Staff

22.571J General Thermodynamics I (A)

(Same subject as 2.451J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 2.451J.
E. P. Gyftopoulos

22.572J Quantum Thermodynamics (A)

(Same subject as 2.452J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 2.452J.
E. P. Gyftopoulos

22.59 Principles of Nuclear Radiation Measurement and Protection (A)

Prereq.: 22.111
G (2)
2-6-4

Combines lectures, demonstrations, and experiments. Covers effects of radiation on persons; control of radiation exposure within applicable standards; theory and use of α, β, γ, and n detectors and spectrometers; use of isotopes, radiation shielding, and dosimetry. Includes demonstrations and experiments using the MIT research reactor, accelerators, and power reactors. Meets with undergraduate subject 22.09, but assignments differ. Students have choices in the experiments they perform. Formerly 22.29 and 22.58.
N. C. Rasmussen, O. K. Harling

Plasmas and Controlled Fusion

22.601 Fusion Energy I (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Basic nuclear physics and plasma physics for controlled fusion. Nuclear physics: fusion cross sections, ignition condition, break-even condition, Lawson criterion, elementary fusion reactor, required plasma parameters. Plasma physics: definition of a plasma, single-particle orbits, Coulomb collisions, fluid model, magnetic fusion configurations, MHD equilibrium and stability, transport and heating. Meets three lecture hours a week with 22.061, but with different assignments and exams.
J. P. Freidberg

22.602 Fusion Energy II (A)

Prereq.: 22.601 or 22.611J
G (2)
3-0-9

Basic engineering and technology of controlled thermonuclear reactors. Current confinement devices: tokamaks, mirrors, alternative concepts. Thermonuclear reactors: systems analysis and design of power reactors, ignition experiments, hybrid reactors. Reactor technologies: neutronics, blanket design, magnet design, first wall, materials and activation, heating technology, tritium handling. Present reactor designs: detailed critical review of prototype reference reactor designs. Safety and environment. Meets with 22.062, but different assignments and exams.
J. P. Freidberg

22.611J Introduction to Plasma Physics I (A)

(Same subject as 6.651J, 8.613J)
Prereq.: 6.014 or 8.07, 6.018 or 8.044, 18.04 or *18.075*
G (1)
3-0-9

See description under subject 8.613J.
A. Bers, M. Porkolab

22.612J Introduction to Plasma Physics II (A)

(Same subject as 6.652J, 8.614J)
Prereq.: 6.651J or 8.613J or 22.611J, *18.076*
G (2)
3-0-9

Linear waves and instabilities in magnetized plasma; solutions of Vlasov-Maxwell equations in homogeneous and inhomogeneous plasmas; conservation principles for energy and momentum; negative energy waves; absolute and convective instabilities. Quasi-linear theory and conservation principles; evolution of unstable particle distribution functions. Collisional transport theory; Fokker-Planck equations; particle diffusion, thermal conductivity, and viscosity in magnetized plasma.
K. Molvig

22.615J MHD Theory of Magnetic Fusion Systems I (A)

(Same subject as 6.653J)
Prereq.: 22.601 or 22.611J or 6.651J or 8.613J
G (1)
3-0-9

Development of ideal MHD theory and application to magnetic fusion systems. MHD model: derivation from Boltzmann equation and single-particle guiding center drifts. Equilibrium: θ pinch, Z pinch, screw pinch, Grad-Shafranov equation, RFP, tokamak, stellarator. Stability: the Energy Principle, kink modes, interchanges, ballooning modes, Suydam criterion, Mercier criterion, Kruskal-Shafranov limit. Impact of MHD equilibrium and stability on RFPs, straight and toroidal tokamaks.
R. Parker

22.616 MHD Theory of Magnetic Fusion Systems II (A)

Prereq.: 6.653J or 22.615J
G (2) **Next offered 1989-90**
3-0-9

Continuation of 22.615J. Theory and application of nonideal MHD theory. Resistive instabilities: tearing modes, resistive interchanges, resistive ballooning modes, nonlinear saturation. Application to Mirnov oscillations, sawtooth oscillations, and major disruptions in a tokamak. Finite Larmor radius stabilization: rotational stabilities in tandem mirrors, internal kinks and interchanges in tokamaks. Guiding center theory: collisionless anisotropic model, equilibrium and stability of simple axisymmetric, nonaxisymmetric and tandem mirrors.
J. P. Freidberg

22.63 Engineering Principles for Fusion Reactors

Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-9

Fusion reactor design considerations: ignition devices, engineering test facilities, and safety/environmental concerns. Magnet principles: resistive and superconducting magnets; cryogenic features. Blanket and first wall design: liquid and solid breeders, heat removal, and structural considerations. Heating devices: radio frequency and neutral beam.
M. Kazimi, J. E. C. Williams

22.64J Plasma Kinetic Theory (A)

(Same subject as 8.621J)
Prereq.: 8.613J
G (1)
3-0-9

See description under subject 8.621J.
T. H. Dupree

22.65J Advanced Topics in Plasma Kinetic Theory (A)

(Same subject as 8.622J)
Prereq.: 8.621J or 22.64J
G (2)
3-0-9

See description under subject 8.622J.
T. H. Dupree

22.66 Plasma Transport Phenomena (A)

Prereq.: 22.611J or 6.651J or 8.613J, 22.64J or 8.621J
G (2) **Not to be offered 1989-90**
3-0-9

Transport theory analyzes the processes by which particle energy, momentum, and mass diffuse across the magnetic field. Develops the collisional classical and neoclassical transport theory of tokamaks (and stellarators), including the theory of MHD equilibrium, particle orbits, and Fokker-Planck operators, for the hydrogenic and impurity ions, as well as injected and alpha particles. Emphasizes connection to experimental confinement and achievement of high beta.
D. J. Sigmar

22.67 Principles of Plasma Diagnostics (A)

Prereq.: 22.611J or 6.651J or 8.613J
G (1) **Not to be offered 1989-90**
3-0-9

Introduction to the physical processes used to measure the properties of plasmas, especially fusion plasmas. Measurements of magnetic and electric fields, particle flux, refractive index, emission and scattering of electromagnetic waves and heavy particles; their use to deduce plasma parameters such as particle density, pressure, temperature, velocity, etc., and hence the plasma confinement properties. Discussion of practical examples and assessments of the accuracy and reliability of different techniques.
I. H. Hutchinson

22.69 Plasma Laboratory (A)

Prereq.: 22.611J or 6.651J or 8.613J or 22.63
G (2)
1-4-4

Introduces the advanced experimental techniques needed for research in plasma physics and useful in experimental atomic and nuclear physics. Laboratory work on vacuum systems, plasma generation and diagnostics, physics of ionized gases, ion sources and beam optics, cryogenics, magnetic field generation, and other topics of current interest; brief lectures and literature references to elucidate the physical bases of the laboratory work. Meets with 22.069, but assignments differ.
I. H. Hutchinson

Nuclear Materials

22.70J Materials for Nuclear Applications (A)

(Same subject as 3.711J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Introductory subject for students who are not specializing in nuclear materials. Applications and selection of materials for use in nuclear applications. Radiation damage, radiation effects, and their effects on performance of materials in fission and fusion environments. Meets with 22.070J, but assignments differ.
R. G. Ballinger

22.71J Physical Metallurgy (A) (Revised Content)

(Same subject as 3.40J)
Prereq.: 3.02, 3.11 or Permission of Instructor
G (1)
3-0-9

See description under subject 3.40J.
K. C. Russell

22.72J Nuclear Fuels (A)

(Same subject as 3.72J)
Prereq.: 3.13 or 3.14 or 22.71J or 3.40J
G (1) **Not to be offered 1989-90**
3-0-9

Behavior of nuclear fuels and fuel element cladding materials in reactor cores. Experimental observations; phenomenological and theoretical modeling of radiation; and thermal-induced effects such as fuel and cladding swelling, fission gas release, and radiation-induced creep. Fuel design, performance modeling, and reliability analysis using state-of-the-art computer codes. Recent developments in advanced nuclear and fusion related core materials.
R. G. Ballinger

22.73J Radiation Effects in Crystalline Solids (A)

(Same subject as 3.73J)
Prereq.: 22.71J or 3.40J, 22.74J or 3.39J
G (2)
3-0-9

Unified treatment based on governing principles in defect structures, thermodynamics, and kinetics of equilibrium and nonequilibrium systems. Discusses phenomena of radiation effects in metals and nonmetals used in fission reactors, fusion reactors, nuclear waste encapsulation, and ion beam technology. Topics include defect generation, damage evolution, radiation-enhanced and induced-rate processes, radiation effects on mechanical and physical properties.
K. C. Russell

22.74J Mechanical Behavior of Materials (A)

(Same subject as 3.39J)
Prereq.: 2.30, 3.11 or 22.71J
G (1)
3-0-9

See description under subject 3.39J.
R. M. N. Pelloux, R. G. Ballinger

22.77 Nuclear Waste Management (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1989-90**
3-0-9

Introduces scientific and engineering aspects of the management of spent fuel, reprocessed high-level waste, uranium mill tailings, low-level wastes, and decommissioning wastes. Fundamental processes and governing equations of radiation and radionuclide transport. Design principles and evaluation methods for geologic waste disposal systems. Interim storage, processing, and transportation technologies. Review of nuclear waste management regulation. Open to qualified undergraduates.
R. K. Lester

General

22.81 Energy Assessment (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Introduction to the broad field of energy, including technological, social, environmental, economic, and political aspects. Energy provision, transformation, and utilization. Development of energy options for the future, and analyses of present regional, national, and international energy programs. For graduate students entering specific energy fields or fields in which energy is important, and who desire a holistic overview. Meets with the undergraduate subject 22.08, but some assignments differ.
M. Miller

22.82 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

22.821 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
R. de Neufville, J. P. Clark

22.841 Nuclear Weapons and Arms Control: Technology and Policy Issues

Prereq.: —
G (1)
4-0-8

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
G. W. Rathjens, J. P. Ruina

22.86 Entrepreneurship

Prereq.: —
G (2)
4-0-5

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
W. C. Flowers

22.901-22.904 Special Problems in Nuclear Engineering (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

For graduate and advanced undergraduate students who wish to conduct a one-term project of a theoretical or experimental nature in the nuclear engineering field, in close cooperation with individual staff members. Arrangement of topic and hours to fit students' requirements.
A. F. Henry

22.911 Seminar in Nuclear Engineering

Prereq.: —
G (1) [P/F]
2-0-1

22.912 Seminar in Nuclear Engineering

Prereq.: —
G (2) [P/F]
2-0-1

Restricted to graduate students engaged in doctoral thesis research.
J. E. Meyer

22.913 Graduate Seminar in Energy Assessment

Prereq.: Permission of Instructor
G (1)
2-0-1

Primarily designed as a communication medium among students conducting research in energy-related areas, and as a means for obtaining critical evaluation of their ongoing research work. Covers topics ranging from technological comparisons to environmental, social, resource, and political impacts, depending on current student and faculty interests.
R. K. Lester

22.914 Graduate Seminar in Energy Assessment

Prereq.: Permission of Instructor
G (2)
2-0-1

Continuation of 22.913.
R. K. Lester

22.92 Advanced Engineering Internship

Prereq.: 22.092
G (1, 2, S) [P/F]
0-6-0

Provides credit for the third and fourth Work Assignments for students affiliated with the Engineering Internship Program. Students register for this subject twice. Students must complete both Work Assignments to receive the academic credit for this subject. Enrollment limited to students in the Engineering Internship Program.
R. G. Ballinger

22.93 Teaching Experience in Nuclear Engineering (A)

Prereq.: Permission of Department
G (1, 2, S)
Arr.

For qualified graduate students interested in teaching as a career. Classroom, laboratory, or tutorial teaching under the supervision of a faculty member. Students selected by interview. Enrollment limited by the availability of suitable assignments. Credits for this subject may not be used toward Master's or Engineer's degrees.
N. E. Todreas

Course 24

Linguistics and Philosophy

Philosophy

24.UR Undergraduate Research

Prereq.: —
U (1, 2) [P/F]
Arr.

Undergraduate research opportunities in Linguistics and Philosophy. For further information, consult the Departmental coordinators.
Linguistics: W. O'Neil.
Philosophy: I. Singer.

24.00 Introduction to the Problems of Philosophy

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Introduction to the problems of philosophy, in particular, to problems in ethics; metaphysics; theory of knowledge; and philosophy of logic, language, and science. A systematic rather than historical approach. Readings from classical and contemporary sources, but emphasis is on examination and evaluation of proposed solutions to the problems.
S. Bromberger, J. Thomson

24.01 Philosophy and Public Affairs

Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

Examination of some practical issues in moral and social philosophy as they occur in theoretical controversies related to contemporary experience. This year's topics center around moral questions of the justifiability of taking life, including euthanasia, abortion, and capital punishment, as well as problems associated with human rights, privacy, and affirmative action. Readings from great writers in the history of philosophy, as well as from contemporary philosophers and Supreme Court cases.
M. Hardimon, P. Hoffman

24.04J Justice (New)

(Same subject as 17.115J)
Prereq.: —
U (1, 2) HASS-D/HUM-D
3-0-9

An examination of alternative theories of justice — utilitarianism, rights theories, social contract theory, and communitarianism — and the implications of those theories for problems of liberty, equality, and community. Readings drawn principally from the work of contemporary political philosophers, including Rawls, Nozick, Dworkin, Walzer, MacIntyre, and Buchanan.
J. Cohen, D. Brink

24.07 Classics in the History of Philosophy

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Introduction to philosophy through its history. Readings in the works of such philosophers as Plato, Aristotle, Aquinas, Descartes, Hume, and Kant. Emphasis on becoming closely acquainted with important historical texts and examining fundamental philosophical issues as they appear in works that usually have been influential in the historical development of Western philosophy.
P. Hoffman

24.08 The Human Mind

Prereq.: —
U (1) HUM-D
3-0-9

Introduces that part of philosophy concerned with the mind, with special attention to the role of science in the study of the mind. Questions discussed: Do people always act selfishly? Is human reason inherently defective? Are social and intellectual differences due to genetic differences? Are some ideas innate? Are the two hemispheres of a human brain really the brains of two different persons? Will computers ever think — indeed, are we, ourselves, computers?
G. Rey

24.09J Classics in Political Philosophy

(Same subject as 17.113J)
Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

An introduction to theories of social justice through a study of classical works in the history of political philosophy, including Plato's *Republic*, Hobbes' *Leviathan*, Locke's *Second Treatise*, Rousseau's *Social Contract*, and Marx's *German Ideology*. Focus on such questions of political order as: Why (if at all) should there be a state? What are the limits of legitimate political authority? Should the state seek to advance a particular view of the good life?
U. Mehta

24.116J Introduction to Cognitive Science

(Same subject as 9.62J)
Prereq.: —
U (1)
3-0-9

See description under subject 9.62J.
D. N. Osherson

24.118 Paradox and Infinity (New)

Prereq.: —
U (2)
3-0-9

Examination of such ancient and contemporary paradoxes as Zeno's, the Liar ("This statement is false"), the Heap, Russell's, Newcomb's, Arrow's, the Surprise Examination, and the Hypergame. Questions discussed include: Is self-reference permissible? Is mathematics logic? Do infinities exist in nature? Cantor's, Dedekind's, and Robinson's theories of infinity, and Gödel's theorems.
G. Boolos

24.119 Minds and Machines

Prereq.: —
U (2)
3-0-9

Examination of problems in the intersection of artificial intelligence, psychology, and philosophy. Issues discussed: whether people are Turing Machines, whether computers can be conscious, limitations on what computers can do, computation and neurophysiology, the Turing test, the analog/digital distinction, Gödel's theorem and mechanism, the relation between simulation and explanation, whether some aspects of mentality are more resistant to programming than others.
R. Stalnaker

24.130 The Meaning of Life

Prereq.: —
U (1)
3-0-9

Problems of human experience approached through philosophical analysis. Questions about the meaning of life, the nature of death, and the creation or discovery of values studied through readings in contemporary philosophy, as well as in the history of philosophy. Enrollment limited.
I. Singer

24.151 Introduction to Philosophy of Language

Prereq.: —
U (2)
3-0-6

Examination of views on the nature of meaning, reference, truth, and their relationships. Other topics may include relationships between language and logic, language and knowledge, language and reality, language and acts performed through its use. No knowledge of logic or linguistics presupposed.
S. Bromberger

24.171 Introduction to Phenomenology

Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

The philosophy of Edmund Husserl. Readings from Logical Investigations, Ideas I, Cartesian Meditations, The Idea of Phenomenology. Discussion on the concepts of intentionality, founding, phenomenological reduction. Survey of the development of phenomenology since Husserl.
G-C. Rota

24.172 Being and Time

Prereq.: —
U (1)
3-0-6

The philosophy of Martin Heidegger and its influence on contemporary thought, stressing existential views on the foundations of science, the critique of classical logic, and Cartesian thought. Readings from Heidegger's *Being and Time.*
G-C. Rota

24.200 Ancient Philosophy (Revised Content)

Prereq.: One Philosophy subject
U (1)
3-0-9

Study of Socrates, Plato, and Aristotle with some attention to pre-Socratic philosophy (e.g., Parmenides and Heraclitus), and Hellenistic philosophy (e.g., Cynicism and Stoicism). Examination of their views on ethics, politics, metaphysics, and the nature of knowledge, with special attention to how these various thinkers formed part of a single tradition of philosophical thought.
D. Brink

24.202 Modern Philosophy: Descartes to Kant

Prereq.: One Philosophy subject
U (2)
3-0-9

Philosophic thought in Europe during the 17th and 18th centuries. The continental rationalists: Descartes, Spinoza, and Leibniz; the British empiricists: Locke, Berkeley, and Hume; Kant.
P. Hoffman

24.203 Aspects of Twentieth-Century Philosophy

Prereq.: One Philosophy subject
U (1)
3-0-9

Study of several major works in European and American philosophy. Emphasis on moral theory in the writings of Bergson, Santayana, Sartre, Freud, and others.
I. Singer

24.204 Existentialism

Prereq.: One Philosophy subject
U (1)
3-0-9

Close investigation of a selection of central texts and themes (e.g., "choice" and "bad faith") in existentialism. Authors to be read include Camus, Kierkegaard, and Sartre.
M. Hardimon

24.208 Kant (New)

Prereq.: One Philosophy subject
U (2)
3-0-9

A thorough study of Kant's *Critique of Pure Reason.* Special topics to be considered include Kant's notion of objectivity and objecthood; the unity of apperception; the criticism of metaphysics; the role of reason in scientific investigation.
M. Hardimon

24.209 Aesthetics of Film and Literature

Prereq.: One Philosophy Subject
U (2)
3-0-9

Study of some major works in both media as relevant to problems in aesthetics, as well as other areas of philosophy. Includes the nature of artistic truth in literature and in film; the ontology of the photographic image; the relationship between verbal and nonverbal expressiveness. Readings in philosophy and literature, and viewing of several films.
I. Singer

24.210 Problems in the Philosophy of Love

Prereq.: One Philosophy subject
U (2)
3-0-9

Philosophical issues in the study of affective bonding: e.g., the distinction between appraisal and bestowal as types of valuation, the nature of idealization, the development of ego ideals, and the relationships among love, desire, emotion, and reason. Readings in recent philosophy.
I. Singer

24.211 Theory of Knowledge

Prereq.: One Philosophy subject
U (2)
3-0-9

Study of problems concerning our concept of knowledge, our knowledge of the past, our knowledge of the thoughts and feelings of ourselves and others, and our knowledge of the existence and properties of physical objects in our immediate environment.
J. Higginbotham

24.221 Metaphysics

Prereq.: One Philosophy subject
U (2)
3-0-9

Study of basic metaphysical issues concerning existence, the mind-body problem, personal identity, causation and its implications for freedom. Classical as well as contemporary readings.
J. Thomson

24.231 Ethics

Prereq.: One Philosophy subject
U (1)
3-0-9

Systematic study of central theories in ethics, including egoism, act and rule utilitarianism, intuitionism, emotivism, rights theories, and contractualism. Discussion and readings also focus on problems associated with moral conflicts, justice, the relationship between rightness and goodness, objective vs subjective moral judgments, moral truth and relativism.
D. Brink

24.233J Political Philosophy

(Same subject as 17.105J)
Prereq.: One Philosophy subject
U (1)
3-0-9

See description under subject 17.105J.
J. Cohen

24.235J Philosophy of Law

(Same subject as 17.109J)
Prereq.: One Philosophy subject
U (2) **Next offered 1989-90**
3-0-9

Examination of fundamental issues in philosophy of law, such as the nature and limits of law and a legal system, and the relation of law to morality, with particular emphasis on the philosophical issues and problems associated with privacy, liberty, justice, punishment, and responsibility. Historical and contemporary readings, including court cases. Permission of instructor required for students without the above prerequisite.
J. Cohen

24.241 Logic I

Prereq.: —
U (1)
3-0-9

Introduction to the aims and techniques of formal logic. The logic of truth functions and quantifiers. The concepts of validity and truth and their relation to formal deduction. Applications of logic and the place of logic in philosophy.
G. S. Boolos

24.242 Logic II

Prereq.: 24.241
U (2)
3-0-9

The central results of modern logic: the completeness of predicate logic, recursive functions, the incompleteness of arithmetic, the unprovability of consistency, the indefinability of truth, the Skolem-Löwenheim theorem, nonstandard models. Permission of instructor required for students without the above prerequisite.
G. S. Boolos

24.244 Modal Logic (New)

Prereq.: 24.241
G (1)
3-0-9

Sentential and quantified modal logic, with emphasis on the model theory ("possible worlds semantics"). Soundness, completeness, and characterization results for alternative systems. Tense and dynamic logics, epistemic logics, as well as logics of necessity and possibility. Applications in philosophy, theoretical computer science, and linguistics.
R. Stalnaker

24.252J Theory of Inductive Inference

(Same subject as 9.66J)
Prereq.: 9.62J
U (2)
3-0-9

See description under subject 9.66J. May *not* count toward HASS requirement.
D. N. Osherson

24.260 Topics in Philosophy (New)

Prereq.: Two subjects in Philosophy
U (2)
3-0-9

Close examination of a single book, or group of related essays, of major significance in recent philosophy. Subject matter varies from year to year. Intended primarily for majors and minors in philosophy.
P. Horwich

24.292 Special Topics in Philosophy

Prereq.: Any two subjects in Philosophy
U (1)
Arr.

Open to qualified students who wish to pursue special studies or projects. Students electing this subject must consult the Department Head.

24.293 Special Topics in Philosophy

Prereq.: Any two subjects in Philosophy
U (2)
Arr.

Open to qualified students who wish to pursue special studies or projects. Students electing this subject must consult the Department Head.

24.400 Proseminar in Philosophy I (A)

Prereq.: Permission of Instructor
G (1)
6-0-18

24.401 Proseminar in Philosophy II (A)

Prereq.: Permission of Instructor
G (2)
6-0-18

Advanced study of the basic problems of philosophy. Intended for first-year graduate students in philosophy.
R. Cartwright

24.410 Topics in the History of Philosophy (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Intensive study of a philosopher or philosophical movement. Content varies from year to year, and subject may be taken repeatedly with permission of instructor and advisor.
P. Hoffman, M. Hardimon

24.501 Problems in Metaphysics (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Metaphysical problems centering around a number of interrelated philosophical issues about the identity across time of physical objects, persons, and events. Readings from both classical and contemporary sources.
R. Stalnaker

24.518J Problems of Mental Representation (A)

(Same subject as 9.671J)
Prereq.: Three Philosophy subjects and Permission of Instructor
G (1)
3-0-9

Topics: the case for mental representation; doubts about the intelligibility of mental representation; the relationship between internal language and external language; does meaning come from mental representations or beliefs; the syntactic theory of the mind; conceptual role semantics and procedural semantics; narrow content; the two-factor theory of the meaning of mental representations.
G. Rey

24.520J Theory of Inductive Inference

(Same subject as 9.661J.)
Prereq.: 9.62J
G (2)
3-0-9

See description under subject 9.661J.
D. N. Osherson

24.601 Topics in Moral Philosophy (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Systematic examination of selected problems in moral philosophy. Content varies from year to year. Subject may be taken repeatedly with permission of instructor and advisor.
J. Thomson, D. Brink

24.611J Political Philosophy (A)

(Same subject as 17.106J)
Prereq.: One Modern Political Philosophy subject
G (1)
3-0-9

See description under subject 17.106J.
J. Cohen

24.625J Philosophies of Social Science (A)

(Same subject as 17.104J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 17.104J.
U. Mehta

24.701 Topics in Logic (A)

Prereq.: 24.241
G (1) **Next offered 1989-90**
3-0-9

Soundness, completeness, and compactness of first-order logic; Löwenheim-Skolem theorems; Craig interpolation lemma; Beth definability theorem; decidability of monadic logic with identity; Turing machines; recursive functions and their definitions; Gödel incompleteness and extensions; undecidability of dyadic logic; Tarski's theorem; nonstandard models of arithmetic.
G. S. Boolos

24.711 Topics in Philosophical Logic (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Problems of ontology, epistemology, and philosophy of language that bear directly on questions about the nature of logic and the analysis of concepts of logical theory, such as logical truth, logical consequence, proof. Content varies from year to year, and subject may be taken repeatedly upon permission of instructor and advisor.
G. Boolos, P. Horwich

24.727 Logic and Language (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Philosophical issues in logic and the analysis of language; the role of logical and linguistic analysis in philosophy, as exemplified in contemporary and near-contemporary work roughly from Carnap (1937) onward. Topics and readings given special emphasis may vary from year to year.
J. Higginbotham

24.810 Topics in Philosophy of Science (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Topics in the foundations of science: the nature of concepts and theories, the distinction between empirical and theoretical knowledge claims, realist and instrumentalist interpretation of such claims, and the analysis of scientific explanation. The central topic varies from year to year; subject may be taken repeatedly with the permission of instructor and advisor.
S. Bromberger

24.811J Topics in Cognition (New)

(Same subject as 9.621J)
Prereq.: Permission of Instructors
G (1)
3-0-9

Major issues in contemporary cognitive science. Topics include similarity judgments and natural kinds; inductive and deductive competence and performance; formal foundations of syntax and semantics; theories of preference and choice.
J. Higginbotham, D. Osherson

24.853 Philosophy of Scientific Development (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Study of problems presented by the conceptual changes that accompany scientific advance. To what extent, for example, do such changes preserve the meaning (or the reference) of scientific terms? Can the cognitive content of a discarded theory be represented in a language adapted to use with its successor? If not, what sort of communication is possible between the proponents of competing theories, and what sense can be made of the notion of scientific progress?
T. S. Kuhn

24.855 Problems in Philosophy of History (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

An examination of major views about problems raised by historical explanation. How can an apparently descriptive enterprise be explanatory? Does its success presuppose laws of human behavior? Does its practice demand an empathy or *Verstehen* unknown in the natural sciences? Readings from such authors as Collingwood, Geertz, Hempel, Taylor, and White.
T. Kuhn

24.891 Special Graduate Topics in Philosophy (A)

Prereq.: —
G (1)
Arr.

24.892 Special Graduate Topics in Philosophy (A)

Prereq.: —
G (2)
Arr.

Open to qualified graduate students in philosophy who wish to pursue special studies or projects. Consult Department headquarters.

Linguistics

24.900J The Study of Language

(Same subject as 21.321J)
Prereq.: —
U (1) HUM-D
3-0-9

What is language? What does knowledge of a language consist of? How do children learn languages? Is language unique to humans? Why are there many languages? How do languages change? Is any language or dialect superior to another? How are speech and writing related? Context for these and similar questions provided by basic examination of internal organization of sentences, words, and sound systems. Assumes no prior training in linguistics.
S. Bromberger

24.901J Language and Its Structure

(Same subject as 21.322J)
Prereq.: 24.900J
U (2)
3-0-9

Detailed examination of fundamental concepts and issues in linguistic theory, with emphasis on explanatory models in linguistics and their bearing on issues in philosophy and cognitive psychology. Phonology: phonetic features, the organization of phonological systems, phonological change; examples from English and other languages. Syntax: deep and surface structures, properties of syntactic rules, syntax, and semantics; a survey of the major syntactic processes of English.
J. W. Harris

24.921 Special Graduate Topics in Linguistics (A)

Prereq.: —
G (1)
Arr.

Open to qualified graduate students in linguistics who wish to pursue special studies or projects. Consult Department headquarters.

24.922 Special Graduate Topics in Linguistics (A)

Prereq.: —
G (2)
Arr.

Open to qualified graduate students in linguistics who wish to pursue special studies or projects. Consult Department headquarters.

24.942 Topics in the Grammar of a Non-Indo-European Language (A)

Prereq.: 24.951
G (2)
3-0-6

Detailed examination of the grammar of a language whose structure is significantly different from English, with special emphasis on problems of interest in the study of linguistic universals. A native speaker of the language assists when possible.
K. L. Hale

24.948J Linguistic Theory and Second Language Acquistion

(Same subject as 21.320J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1989-90**
3-0-6

Reading and discussion of current linguistic theory, first language acquisition research, and data concerning adult second language acquisition. Focus on development of a theory of second language acquisition within a theory of Universal Grammar. Emphasis on syntactic, lexical, and phonological development. Examination of ways in which this body of data confronts theories of language.
W. O'Neil, S. Flynn

24.949J Language Acquisition (A)

(Same subject as 9.601J)
Prereq.: Permission of Instructor
G (1, 2) **Not to be offered 1989-90**
3-0-6

See description under subject 9.601J.
Term 1: *K. Wexler*
Term 2: *S. Pinker*

24.951 Introduction to Linguistics I: Syntax (A)

Prereq.: 24.901J
G (1)
3-0-9

Introduction to theories of syntax underlying work currently being done within the lexical-functional and government-binding frameworks. Organized into three interrelated parts, each focused upon a particular area of concern: 1) phrase structure, 2) the lexicon, and 3) principles and parameters. Grammatical rules and processes constitute a focus of attention throughout the course, serving to reveal both modular structure of grammar and interaction of grammatical components.
K. L. Hale

24.952 Introduction to Linguistics III: Theory of Grammar (A)

Prereq.: 24.951
G (2)
3-0-9

Problems in constructing an explanatory theory of grammatical representation. Topics drawn from current work on anaphora, case-marking, control, argument structure, Wh- and related constructions. Study of language-particular parameters in the formulation of linguistic universals.
Staff

24.956 Introduction to Linguistics IV: Universal Grammar (A)

Prereq.: 24.951
G (1)
3-0-9

The nature of linguistic universals that make it possible for languages to differ and place limits on these differences. Study of selected problem areas, showing how data from particular languages contribute to the development of a strong theory of universal grammar and how such a theory dictates solutions to traditional problems in the syntax of particular languages.
Staff

24.957 Introduction to Linguistic Theory at an Advanced Level (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Discussion of conceptual and methodological issues: goals of linguistic theory and its place in the study of thought and behavior; descriptive and explanatory theories; the nature, use, and acquisition of knowledge of language compared with other cognitive systems; relations of form, meaning, and language use. Examination of theories of transformational generative grammar as they have evolved and are now being pursued: theory of base, transformations, semantic interpretation of formal structures, logical form, and conditions on the form and functioning of rules.
N. A. Chomsky

24.958 Linguistic Structure (A)

Prereq.: 24.952 or 24.957
G (1)
3-0-9

Current work on topics in syntax and semantics. Permission of instructor required.
R. Larson

24.959 Workshop in Syntax and Semantics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

An intensive group tutorial/seminar for discussion of research being conducted by participants. No auditors allowed.
J. Higginbotham

24.960 Seminar in Semantics

Prereq.: 24.973
G (1)
3-0-9

Examination in depth of the comparative syntax and semantics of some particular construction type, with choice of construction varying in different years. Topic for 1988-89: grammar and interpretation of functional categories (e.g., D, I, K, Deg) in cross-linguistic perspective, with particular attention to specifier systems.
K. Hale, R. Larson

24.961 Introduction to Linguistics II: Phonology

Prereq.: —
G (1)
4-0-5

Aims and principles of a scientific description of the phonic aspect of language. The mechanism and acoustics of speech. Distinctive features as the descriptive framework. The phoneme. The phonemic system of a language. The interrelations between phonology and other linguistic levels. Some problems of historical phonology. Practical exercises. This subject is a core offering in Cognitive Science.
M. Halle

24.962 Advanced Phonology (A)

Prereq.: 24.961
G (2)
3-0-9

Continuation of 24.961. Special emphasis on problem solving.
M. Halle

24.964 Theory of Phonology (A)

Prereq.: 24.961
G (1)
3-0-9

Review in depth of one of four major topics in modern phonology: stress and meter (1987-88), tone (1988-89), syllable structure (1989-90).
M. Kenstowicz

24.965 Morphology (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
3-0-9

Structure of the lexicon and its function in grammar. Properties of word-formation rules. Problems of selection, productivity, compositionality. Systems of inflectional categories: case, tense. Phonological aspects of word structure: allomorphy, cyclic phonology, constituent structure, boundaries. Detailed analysis of languages with complex morphology.
M. Halle, D. Steriade

24.966J Laboratory on the Physiology, Acoustics, and Perception of Speech (A)

(Same subject as 6.542J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
2-2-8

See description under subject 6.542J.
D. H. Klatt

24.968J Speech Communication (A)

(Same subject as 6.541J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 6.541J.
S. J. Keyser, K. N. Stevens

24.969 Workshop in Phonology and Morphology (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

An intensive group tutorial/seminar for discussion of research being conducted by participants. No auditors are allowed.
M. Halle

24.970 Introduction to Semantics

Prereq.: Permission of Instructor
G (1)
3-0-9

Basic issues of form and meaning in formalized and natural languages. Conceptual, logical, and linguistic questions about truth, reference, and modal and intensional notions. The role of grammar in language use; context-dependency. Ambiguities of structure and of meaning; dimensions of semantic variation in syntax and the lexicon.
J. Higginbotham

24.973 Topics in Logic and Semantics (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Current work on semantics and questions of logic and meaning for syntactic systems in generative grammar.
R. Larson

24.979 Semantic Theory (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Seminar on current research in semantics and generative grammar. In addition to reading and discussion, students may present original research. Topics may vary from year to year.
J. Higginbotham, R. Larson

24.982 Linguistic Change (A)

Prereq.: 24.951, 24.961
G (2)
3-0-9

Review of instances of change in phonology, morphology, and syntax. Examples to be drawn from various language families, Indo-European, as well as others. An attempt to develop a general theory of linguistic change.
Staff

24.992 Survey of General Linguistics I

Prereq.: Permission of Instructor
G (1)
3-0-9

Reading and discussion of certain important papers in syntax, semantics, and phonology designed to familiarize the student with central ideas in current linguistic research. Selection of papers and organization of discussion is primarily in the hands of seminar participants.
W. O'Neil

24.993 Tutorial in Linguistics and Related Fields (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Individual or small-group tutorial in which students, under the guidance of a faculty member, explore the interrelations with linguistics of some specified area. Consult Department headquarters.

HST

Health Sciences and Technology

Students wishing to take HST 011-191 must file an application in Room E25-519.

HST subjects numbered 011 through 310 are scheduled according to the Harvard Medical School academic calendar which is different from that of MIT. Students whose graduation depends upon completing one or more of these courses should take particular care regarding schedule.

HST 011 Human Functional Anatomy (A)

Prereq.: Permission of Instructor
G (1)
2-9-10

Lectures, detailed laboratory dissections and prosections provide a thorough exploration of the gross structure and function of the human body. Fundamental principles of bioengineering are employed to promote analytical approaches to understanding the body's design. The embryology of major organ systems is presented, together with certain references to phylogenetic development, as a basis for comprehending anatomical complexity. Correlation clinics stress both normal and abnormal functions of the body; guest lecturers focus on current problems in organ system research. (HST/MD students may register under HST 010, graded P/F.)
F. A. Jenkins, Jr., L. Gehrke, W. C. Hayes, and Associates

HST 021 Bone and Connective Tissue (A)

Prereq.: Permission of Instructor
G (J)
1-2-4

Growth and development of normal bone and joints, the process of mineralization, the biophysics of bone and response to stress and fracture, calcium and phosphate homeostasis and regulation by parathyroid hormone and vitamin D, and the pathogenesis of metabolic bone diseases and disease of connective tissue and joints, with consideration of possible mechanisms and underlying metabolic derangements. Meets first half of the term. Enrollment limited. (HST/MD students may register under HST 020, graded P/F.)
D. R. Robinson, W. C. Hayes, J. T. Potts, Jr., A. L. Schiller, C. Sledge

HST 031 Human Pathology (A)

Prereq.: 7.01, 8.01, 8.02
G (1)
4-4-8

Introduction to the organization, structure, and function of normal cells and tissues; pathologic principles of cellular injury, inflammation, circulatory disorders, immunologic injury, infection, nutritional disorders, growth disorders, neoplasia, and radiation injury in humans. Lectures, conferences, laboratories with examination of microscopic and gross specimens, and autopsy case studies. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 030, graded P/F.)
H. Goldman, A. K. Abbas, G. R. Dickersin, A. H. Lichtman, Associates

HST 041 Mechanisms of Microbial Pathogenesis (A)

Prereq.: 7.01, 7.05
G (1)
3-6-5

Deals with the mechanisms of pathogenesis of bacteria, viruses, and other microorganisms. Approach spans mechanisms from molecular to clinical aspects of disease. Topics selected for intrinsic interest and cover the demonstrated spectrum of pathophysiologic mechanisms. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 040, graded P/F.)
P. Schaffer, J. Mekalanos, H. Simon

HST 061 Endocrinology (A)

Prereq.: 7.01, 7.05
G (1)
6-0-6

Physiology and pathophysiology of the human endocrine system. Four hours of lecture each week concern individual parts of the endocrine system. Topics also include assay techniques, physiological integration, etc. At frequent clinic sessions, patients are presented who demonstrate clinical problems considered in the didactic lectures. Enrollment limited, permission of instructor required. (HST/MD students may register under HST 060, graded P/F.)
R. Arky, S. H. Ingbar, W. Kettyle

HST 071 Human Reproductive Biology (A)

Prereq.: 7.01, 7.05, Permission of Instructor
G (2)
2-4-3

Lectures, laboratory sessions, and clinical case discussions designed to provide the student with a clear understanding of the physiology, endocrinology, and pathology of human reproduction. Emphasis is on quantitative analytic techniques and the role of technology in reproductive science. The course also involves the student in the wider aspects of reproduction, such as prenatal diagnosis, *in vitro* fertilization, abortion, menopause, and contraception. (HST/MD students may register under HST 070, graded P/F.)
H. Klapholz, C. Millette, S. Driscoll, and Associates

HST 081 Hematology (A)

Prereq.: 7.05
G (1) **Next offered 1989-90**
3-6-4

An intensive survey of the biology, physiology, and pathophysiology of blood and the blood-forming organs with systematic consideration of hematopoiesis, the "formed elements," blood coagulation, blood groups and immunoglobulins, and other plasma proteins. Emphasis given equally to didactic discussion and analysis of clinical problems. Meets second half of the term. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 080, graded P/F.)
W. S. Beck, W. H. Churchill, R. D. Rosenberg

HST 091 Cardiovascular Pathophysiology (A)

Prereq.: 7.01 or 18.01, 18.02
G (2)
3-3-9

Normal and pathologic physiology of the heart and vascular system. Emphasis includes hemodynamics, electrophysiology, gross and microscopic pathology, and clinical correlates of cardiovascular function in healthy and in a variety of disease states. Special attention given to congenital, rheumatic, hypertensive, arteriosclerotic, and coronary heart disease and cardiomyopathy. Enrollment: lectures — open, laboratory — limited. Permission of instructor required. (HST/MD students may register under HST 090, graded P/F.)
W. H. Abelmann, J. T. Fallon, W. Gamble, R. G. Mark, B. C. Berk, R. J. Cohen

HST 101 Respiratory Pathophysiology (A)

Prereq.: 7.01, 7.05, 8.01
G (2)
1-2-5

Lectures, seminars, and laboratories cover the development of the lung; its histology and cellular function; and physics of gases, physiology, and gas exchange as it relates to health and disease. Problems of gas transport and acid-base balance are reviewed; pathophysiology of common respiratory disorders presented. Sessions with patients with lung disease. For M.D. candidates and other students with background in science. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 100, graded P/F.)
D. C. Shannon, L. Ginns, H. Kazemi, E. Mark, C. A. Hales, J. C. Weaver

HST 111 Renal Pathophysiology (A)

Prereq.: 7.01, 7.05
G (2)
2-1-5

Topics include the normal and pathologic functioning of the kidney. Emphasis on electrolyte and water metabolism — the role of Na+, K+, H+, water, and renal failure. Included also, the pathophysiology of clinical renal disorders such as acute and chronic glomerulonephritis, pyelonephritis, and vascular disease. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 110, graded P/F.)
C. Coggins, H. Rennke, J. V. Bonventre L. Fang

HST 121 Gastroenterology (A)

Prereq.: 7.01, 7.05, 8.01
G (1) **Next offered 1989-90**
3-6-4

Presents the anatomy, physiology, biochemistry, biophysics, and bioengineering of the gastrointestinal tract and associated pancreatic, liver, and biliary systems. Emphasis on the molecular and pathophysiological basis of disease where known. Covers gross and microscopic pathology and clinical aspects. Formal lectures given by core faculty, with some guest lectures by local experts. Selected seminars conducted by students with supervision of faculty. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 120, graded P/F.)
M. C. Carey, D. Antonioli, R. H. Schapiro, J. R. Wands, J. L. Madara

HST 131J The Human Nervous System: The Neurosciences (A)

(Same subject as 9.014J)
Prereq.: 7.01, 7.05, Permission of Instructor
G (1)
6-3-6

This subject encompasses an introduction to 1) the anatomy and fine structure of the mammalian central nervous system (brain and spinal cord), 2) the physiology of nerve cells and of neural systems (special emphasis on sensory, motor, and neuroendocrine systems), 3) neurotransmitter actions and neurotransmitter-coded neural systems in the brain, 4) molecular neurobiology and neurogenetics. Included in the course are five clinical demonstrations. (HST/MD students may register under HST 130, graded P/F.)
A. M. Graybiel, W. G. Quinn, M. Sur, P. H. Schiller, E. Bizzi, and clinical demonstrations by M. A. Samuels, H. R. Tyler, R. R. Young, T. D. Sabin, M. P. Alexander.

HST 133 Pathophysiology of the Nervous System (A)

Prereq.: HST 131J
G (2)
4-0-8

Discussion of physiological and biochemical mechanisms of peripheral and central nervous systems' diseases. Lectures emphasize advances in the basic sciences as they apply to the muscular dystrophies, myasthenia gravis, peripheral neuropathies, pain and nociception, suprasegmental control of movement, multiple sclerosis, Alzheimer's and Huntington's diseases, epilepsy, sleep and biological rhythms, strokes, and disorders of emotion and language. Enrollment limited. Permission of instructor required. (HST/MD students may register under HST 132, graded P/F.)
M. A. Moskowitz

HST 141 Molecular Basis of Some Clinical Disorders (A)

Prereq.: 7.05
G (1)
4-0-6

Conducted as a seminar to study a variety of human diseases and the underlying molecular and biologic basis for the pathogenesis and pathophysiology of the disorders. Lectures by faculty and seminars conducted by students, with tutorials and supervision by faculty. Whenever possible, appropriate patients presented and discussed. Appropriate for students who have had a course in biochemistry and/or molecular biology. (HST/MD students may register under HST 140, graded P/F.)
P. M. Gallop, I. M. London, Associates

HST 176 Cellular and Molecular Immunology (A)

Prereq.: 7.05
G (1)
4-0-8

Course covers cellular interactions in immune responses, general principles governing the expression of lymphocyte receptor genes, effector functions of lymphokines and monokines and pathogenesis of immunologically mediated diseases. Course consists of lectures and conferences in which relevant clinical issues are discussed, and journal clubs in which recent experimental work is presented and analyzed by students. Sections of the course are integrated with HST 031, Human Pathology. Enrollment is limited to 40 students. (HST/MD students may register under HST 175, graded P/F.)
A. K. Abbas, A. H. Lichtman, J. S. Pober, Associates

HST 191 Statistical Planning and Analysis of Biomedical Investigations (A)

Prereq.: 18.02
G (J)
3-0-3

Introduces statistical logic and technique as a basis for clinical decisions and scientific inference. Students learn to perform elementary statistical calculations and acquire the concepts and vocabulary to read biomedical literature critically and communicate productively with statistical professionals. Includes probability theory, normal sampling, chi-square and t-tests, analysis of variance, linear regression, and survival analysis. Case studies include applications to diagnostic screening, clinical drug trials, and physiological experiments. Emphasis on experimental studies rather than epidemiology. (HST/MD students may register under HST 190, graded P/F.)
H. Feldman

HST 196 Teaching Health Sciences and Technology

Prereq.: —
G (1, 2, S) [P/F]
Arr.

For teaching assistants in HST where the teaching assignment is approved for academic credit by the Department.
R. G. Mark

HST 199 Research in Health Sciences and Technology

Prereq.: Permission of Instructor
G (1, 2, S) [P/F]
Arr.

For research assistants in HST where the assigned research is approved for academic credit by the Department. Hours are arranged with research supervisor.
R. G. Mark

HST 200 Introduction to Clinical Medicine (A)

Prereq.: Permission of Instructor
G (2) [P/F]
9-25-12

February through May, Monday, Wednesday, Friday. Students learn the basic skills involved in examination of the patient and are introduced to history taking and patient interview. Students exposed to clinical problems in medicine, surgery, and pediatrics in groups of two or three students under one faculty member. Findings reported through history taking and oral presentation of the cases to the class. An intensive subject serving as prerequisite to clinical clerkships. Enrollment limited to students in M.D. Program.
E. Braunwald, W. H. Churchill, D. Brooks, J. Muller, Associates

HST 201 Introduction to Clinical Medicine and Medical Engineering I (A)

Prereq.: HST 011, HST 031, HST 091, HST 101, HST 111, HST 131J, 7.05
G (J)
0-20-0

Required for doctoral students in MEMP program. Students 1) develop skill in patient interviewing and physical examination; 2) become proficient at organizing and communicating clinical information in both written and oral forms; 3) begin integrating history, physical, and laboratory data with pathophysiologic principles; and 4) become familiar with the clinical decision making process and broad economic, ethical, and sociological issues involved in patient care. Permission of instructor required.
R. G. Mark, W. Ruth, C. J. Hatem, Associates

HST 202 Introduction to Clinical Medicine and Medical Engineering II (A)

Prereq.: HST 201
G (S)
0-20-0

Strengthens the skills developed in HST 201 through a six-week clerkship in medicine at Mount Auburn Hospital. Students serve as full-time members of a ward team and participate in longitudinal patient care. In addition, students participate in regularly scheduled teaching conferences focused on principles of patient management.
C. J. Hatem, R. G. Mark, Associates

HST 203 Clinical Experience in Medical Engineering and Medical Physics (A)

Prereq.: HST 201, HST 202
G (1, 2, S) [P/F]
0-40-0

An individually arranged full-time three-month directed study in a clinical environment where active medical engineering/medical physics investigation is in progress. Students are actively engaged in patient care, particularly those aspects that interface closely with technology. Students also focus on in-depth exploration of the technical and research area. Term paper required.
E. G. Cravalho, R. G. Mark, Associates

HST 300 Clinical Management and Physiology of Surgical Intensive Care Patients (A) (New)

Prereq.: Clerkship in Medicine and Permission of Instructor
G (1, 2, S) [P/F]
0-15-0

One-month course designed to teach quantitative applications of basic physiologic and pharmacologic concepts to synthesize diagnoses and treatments for critically ill patients. Emphasis also on principles, applications, and limitations of equipment used to monitor and treat patients in intensive care units. Students participate in individual and group discussions, and are assigned clinically relevant basic science readings and given supervised responsibilities for one or more ICU patients. Students are expected to give brief oral reports weekly and a more comprehensive presentation integrating physiologic concepts with clinical problems at the end of the month.
R. S. Teplick, D. J. Cullen, R. S. Wilson

HST 310 Advanced Cardiology (A) (New)

Prereq.: Clerkship in Medicine at HMS and Permission of Instructor
G (1, 2, S)
0-30-0

Course combines clinical experience and evaluation of patients with a broad range of cardiac problems on a busy consultation service, with opportunities to follow patients in the non-invasive and invasive cardiac laboratories. During a second and, electively, third month, students select an area of cardiovascular medicine for either clinical or investigative in-depth study. Students also present a seminar on their topic.
W. H. Abelmann, D. S. Baim, P. C. Come, W. Grossman, R. G. McKay, J. P. Morgan, J. A. Parker, R. C. Pasternak

HST 521J Biomedical Transport Phenomena (A)

(Same subject as 10.49J)
Prereq.: 10.301, 10.302
G (2)
2-0-4

See description under subject 10.49J.
C. K. Colton, W. M. Deen

HST 530J Ultrasound: Physics, Biophysics, and Technology (A)

(Same subject as 2.76J, 6.562J)
Prereq.: Permission of Instructor
G (1) **Not to be offered 1989-90**
4-1-7

See description under subject 2.76J.
P. P. Lele, F. R. Morgenthaler

HST 531J Lasers, Microwaves, Ultraviolet, Magnetic Fields, and Ultrasound in Biomedical Sciences (A)

(Same subject as 2.762J)
Prereq.: Permission of Instructor
G (1) **Next offered 1989-90**
4-1-7

See description under subject 2.762J.
P. P. Lele, Staff

HST 541J Quantitative Physiology: Cells and Tissues

(Same subject as 2.791J, 6.021J)
Prereq.: 2.02 or 6.002 or 6.071; 8.02; 18.03
U (1)
4-2-6

See description under subject 6.021J.
T. F. Weiss, R. C. Lee, I. V. Yannas

HST 542J Quantitative Physiology: Organ Transport Systems

(Same subject as 2.792J, 6.022J)
Prereq.: 2.20, *HST 541J*, 2.791J, 6.013
U (1)
3-2-7

See description under subject 6.022J.
R. G. Mark, R. D. Kamm

HST 543J Quantitative Physiology: Sensory and Motor Systems

(Same subject as 2.793J, 6.023J, 16.351J)
Prereq.: 2.02 or 6.003 or 16.30
U (2)
3-2-7

See description under subject 6.023J.
L. R. Young, R. W. Mann, L. S. Frishkopf

HST 544J Fields, Forces, and Flows: Background for Physiology (A)

(Same subject as 6.561J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 6.561J.
A. J. Grodzinsky

HST 550J Computers and Patient Care

(Same subject as 6.523J)
Prereq.: —
G (2)
2-0-4

An overview of present and potential uses of computers in patient care. Topics: medical-information systems, input of physician progress notes and orders, ambulatory medical record, automated medical consultation and diagnosis, medical education and clinical simulations, data analysis in clinical investigations. Open to undergraduates.
G. O. Barnett

HST 560J Biological and Medical Applications of Radiation and Radioisotopes (A)

(Same subject as 22.55J)
Prereq.: 22.111 or 8.272
G (2)
4-0-8

See description under subject 22.55J.
Staff

HST 561J Principles of Medical Imaging (A)

(Same subject as 2.761J, 22.56J)
Prereq.: Permission of Instructor
G (1)
4-0-8

See description under subject 22.56J.
V. Wedeen, P. P. Lele

HST 568J Radiation Biophysics (A)

(Same subject as 22.57J)
Prereq.: 22.111
G (1)
4-0-8

See description under subject 22.57J.
Staff

HST 569 Photomedicine (A) (New)

Prereq.: 7.01, 7.05, 8.02, or equivalent
G (2)
3-0-9

Course is designed to provide a fundamental understanding of the interaction of ultraviolet, visible, and infrared radiation with tissue, and the therapeutic uses of this interaction with particular emphasis on the applications of lasers. Basic concepts in electromagnetic radiation, its interaction with molecules and the subsequent chemical, biological, and physical responses are presented. Specific examples from three broad areas of photobiology, ultraviolet radiation effects, photosensitization and laser photomedicine, are studied in depth.
J. A. Parrish, R. R. Anderson, I. E. Kochevar, E. G. Cravalho

HST 570J Biomedical Instrumentation Electronics

(Same subject as 2.781J, 16.608J)
Prereq.: Permission of Instructor
G (S)
6-6-6

Introduction to modern computer-based instrumentation through a major bioengineering laboratory project in which each student develops electronic circuits, interfaces them to a microcomputer, and combines them to form an instrument. Classroom material focuses on electronic circuit elements, networks, signal and system representations, logic and digital design, elementary programming, and physiological background. No background in electrical engineering or programming required.
S. K. Burns, D. Rowell

HST 575J Bioelectronics Project Laboratory

(Same subject as 6.121J)
Prereq.: 6.002 or 6.071
U (2) LAB
2-8-2

See description under subject 6.121J.
S. K. Burns, R. G. Mark

HST 582J Biomedical Signal Processing (A)

(Same subject as 6.555J, 16.356J)
Prereq.: 6.003
G (2)
3-6-3

Fundamentals of digital signal processing of particular relevance to problems in biomedical research and clinical medicine. Basic principles and algorithms for data acquisition and display, filtering, and feature extraction. Laboratory projects provide practical experience in processing physiologic data, with examples from neurophysiology, cardiology, and speech-processing.
B. Delgutte, W. M. Siebert, P. Albrecht

HST 584J Magnetic Resonance — Analytic, Biochemical, and Imaging Techniques (A)

(Same subject as 22.561J)
Prereq.: Permission of Instructor
G (2)
3-0-12

Introduction to basic NMR theory, including a quantum mechanical description of the NMR experiment. Examples of biochemical data obtained using NMR summarized along with other related experiments. Detailed study of NMR imaging techniques includes discussions of basic cross-sectional image reconstruction, image contrast, flow and real-time imaging, and hardware design considerations. Exposure to laboratory NMR spectroscopic and imaging equipment included.
B. Rosen

HST 585J Biomedical Measurements (A)

(Same subject as 6.566J)
Prereq.: Permission of Instructor
G (1)
3-3-6

Fundamental principles of measurements. Transducers and instrumentation interfaced to biological systems in medicine, research, and biotechnology. Principles illustrated using thermal, electrical, chemical, and mechanical measurements. Project-oriented laboratory provides practical exposure to medical engineering concepts, and methods for computer-based acquisition and interpretation of information obtained via measurements on biological systems. Some background in electronics and life sciences is assumed.
J. C. Weaver, D. J. Edell, R. S. Newbower

HST 590 Biomedical Engineering Seminar

Prereq.: —
G (1, 2)
1-0-0

Biweekly graduate seminars presented by HST students. Course is designed to provide students with a broad exposure to current research in biomedical engineering and medical physics. Occasional visiting speakers, scheduled between student presentations, are used to broaden the scope of the seminars.
D. J. Edell

HST 591 Biomedical Engineering Research Seminar

Prereq.: —
G (1, 2)
2-0-0

Development of professional speaking skills in the communication of research progress. Students present their research, emphasizing clear statement of the goals, significance, and current status of their work. Confidential, written feedback given by each member of the audience. Required of all students affiliated with the HST Biomedical Engineering Center.
J. C. Weaver

HST 595 Tutorial in Medical Engineering and Medical Physics (A)

Prereq.: —
G (1, 2) [P/F]
2-0-0

Hospital-based tutorial for medical engineering/medical physics doctoral students. Small group sessions to examine state-of-the-art applications of technology to patient care; explore active research programs with major biomedical engineering content; and discuss the economic, social, and ethical implications of technology in health care.
R. G. Mark

HST 598 Special Topics in Medical Engineering and Medical Physics

Prereq.: —
U (1, 2, S)
Arr.

For undergraduates desiring to carry on substantial projects of their own choosing in medical engineering or medical physics. Work may be of experimental, theoretical, or design nature. Coordinator: E. G. Cravalho.

HST 599 Special Topics in Medical Engineering and Medical Physics (A)

Prereq.: Permission of Instructor
G (1, 2, S)
Arr.

Assigned reading and special problems or research on special topics, either theoretical, experimental, or clinical. Arranged on individual basis with instructor.
Coordinator: E. G. Cravalho.

HST 900 Topics in the Economics of Health Care (A)

Prereq.: —
G (J) [P/F]
2-0-4

Introduction to some of the problems in the resource allocation of the health-care sector. Brief introduction to economic theory. Topics: rising health costs, national health insurance, cost-benefit analysis and optimization, regulation and the structure of the industry (centralization vs decentralization), technology assessment, and planning clinical trials. Emphasis more on posing the important questions and examining different methods of analysis rather than arriving at definitive answers.
A. Detsky

HST 901J Health Economics

(Same subject as 14.21J)
Prereq.: 14.01
U (2) HASS
3-0-6

See description under subject 14.21J.
J. E. Harris

HST 902 Current Economic and Regulatory Problems in Toxicology

Prereq.: Permission of Instructor
G (1)
3-0-9

Examination of tools available to economists and toxicologists for decision making in a regulatory environment. Case method used with lectures on topics such as multistage carcinogenesis, diet and cancer, carcinogenesis and mutagenesis testing, some aspects of FDA and EPA regulatory law, extrapolation of test results, decision making, and risk assessment.
J. E. Harris

HST 903J Health Economics Seminar (A)

(Same subject as 14.286J)
Prereq.: 14.04
G (2)
3-0-9

See description under subject 14.286J.
J. E. Harris

HST 920J Health Technology (A)

(Same subject as 15.136J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 15.136J.
S. N. Finkelstein

HST UR Undergraduate Research in Health Sciences and Technology

Prereq.: —
U (1, 2, S) [P/F]
Arr.

Extended participation in the work of a faculty member or research group. Research is arranged by mutual agreement between the student and a member of the faculty of the Harvard-MIT Division of Health Sciences and Technology, and may continue over several terms. Registration requires submission of a written proposal, signed by the faculty supervisor. A summary report must be submitted at the end of each term.
E. G. Cravalho

SP Special Programs

Project Interphase

SP 100 Special Summer Program (Project Interphase)

Prereq.: —
U (S)
Arr.

A program intended to assist freshmen from underrepresented minority groups in developing and sharpening their knowledge of and facility with those quantitative skills and verbal concepts that are essential for successful academic performance at MIT. Classes are held in four academic areas: chemistry, humanities, mathematics, and physics. Staff includes MIT faculty members and graduate students who are assisted by interested and committed graduate and undergraduate tutors. An introduction to MIT'S resources and academic programs and services for freshmen is also offered. Credit arranged with an 18-unit maximum.
A. Davison

Experimental Study Group

SP 211 ESG (Experimental Study Group)

Prereq.: —
U (1)
Arr.

SP 212 ESG (Experimental Study Group)

Prereq.: —
U (2)
Arr.

A flexible academic program for freshmen in mathematics, humanities and social sciences, physics, and chemistry. Credit available for General Institute Requirements, as well as special educational interests, through tutorials, small classes, and independent projects. Subjects may also be taken in the regular curriculum in conjunction with work done in ESG. Staff includes MIT faculty, instructors, graduate students, and undergraduate tutors who are interested in teaching in a small, informal community.
J. K. Vandiver

SP 221 ESG (Experimental Study Group)

Prereq.: SP 211 and/or SP 212
U (1)
Arr.

SP 222 ESG (Experimental Study Group)

Prereq.: SP 211 and/or SP 212
U (2)
Arr.

Continuation of ESG for sophomores.
J. K. Vandiver

SP 231 ESG Undergraduate Teaching

Prereq.: SP 211 and/or SP 212
U (1)
Arr.

SP 232 ESG Undergraduate Teaching

Prereq.: SP 211 and/or SP 212
U (2)
Arr.

An opportunity to tutor students, run study groups, and lead seminars in mathematics, physics, chemistry, and humanities and social sciences in ESG under staff supervision. Permission of appropriate ESG staff member required.
J. K. Vandiver

SP 290-SP 299 ESG Special Topics

Prereq.: —
U (1, 2)
Arr.

Independent study for ESG undergraduates interested in pursuing experimental projects or research of their own choosing. Close supervision and regular meetings will supplement individual work. Written proposals and written final reports are also required. Permission of the instructor is necessary.
J. K. Vandiver

Concourse Program

SP 311 Concourse Program

Prereq.: —
U (1)
Arr.

SP 312 Concourse Program

Prereq.: —
U (2)
Arr.

An integrative program for the freshman year. Staff includes faculty from the Schools of Science, Engineering, and Humanities and Social Science. Credits in Concourse fulfill the General Institute Requirements and are so recorded.
R. M. Rose

Integrated Studies Program

SP 351 Integrated Studies Program

Prereq.: —
U (1)
Arr.

SP 352 Integrated Studies Program

Prereq.: —
U (2)
Arr.

A program for the freshman year that satisfies the General Institute Requirements in mathematics, physics, chemistry, and two Humanities Distribution subjects. Features linked calculus/physics sections, close tutoring, and an introduction to the societal context of science and engineering. Staff includes faculty from the School of Humanities and Social Science, and from the Schools of Science and Engineering.
A. Steinberg

SP 353 ISP (Integrated Studies Program)

Prereq.: SP 351 and/or SP 352 or Permission of ISP Director
U (1)
Arr.

SP 354 ISP (Integrated Studies Program)

Prereq.: SP 351 and/or SP 352
U (2)
Arr.

Continuation of ISP for upperclass students.
A. Steinberg

Women's Studies Program

SP 401 Introduction to Women's Studies

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

An interdisciplinary subject that draws on literature, history, psychology, philosophy, anthropology, and feminist theory to: 1) examine our cultural assumptions about gender, 2) trace the effects of the new scholarship on traditional disciplines, and 3) increase awareness of the history and experience of women as half the world's population.
I. de Courtivron

SP 402 Contemporary Issues in Women's Studies — Gender, Work, and Politics: Some Major Questions in Modern American Feminism
(Revised Content)

Prereq.: Permission of Instructor
U (2) HASS
3-0-9

Privacy, community, and material culture; segregated labor markets and comparable worth; styles of political participation. Readings are drawn from both historical and current debates on these three themes. Discussion focuses on the ramifications of these issues in public policy.
J. Conway

SP 404 Special Topics in Women's Studies

Prereq.: Permission of Instructor
U (1, 2)
Arr.

SP 405 Special Topics in Women's Studies

Prereq.: Permission of Instructor
G (1)
Arr.

Individual supervised work for students who wish to study topics not covered in the regular Women's Studies offerings. Before registering for this subject, students must plan a course of study with some member of the Women's Studies faculty and secure the Director's approval.
I. de Courtivron

SP 420J American Women's History

(Same subject as 21.416J)
Prereq.: —
U (1) HUM-D
3-0-9

See description under subject 21.416J.
E. Fitzpatrick

SP 431J New Women's Voices

(Same subject as 21.299J)
Prereq.: —
U (2) HASS **Not to be offered 1989-90**
3-0-6

See description under subject 21.299J.
E. Waldstein

SP 432J Sex Roles in Fiction: Europe and Latin America

(Same subject as 21.297J)
Prereq.: —
U (1) HUM-D **Next offered 1989-90**
3-0-9

See description under subject 21.297J.
M. Resnick, L. Kampf

SP 434J Courtship Themes in Romance Literature

(Same subject as 21.300J)
Prereq.: —
U (2) HASS **Next offered 1989-90**
3-0-6

See description under subject 21.300J.
M. Resnick

SP 436J Women In Literature

(Same subject as 21.041J)
Prereq.: One subject in Literature
U (2) HASS
3-0-9

See description under subject 21.041J.
Information: A. C. Kibel, I. de Courtivron

SP 438J Major Authors

(Same subject as 21.175J)
Prereq.: Two subjects in Literature
U (2) HASS
3-0-9

Topic for 1988-89: Jane Austen — Text and Context. See description under subject 21.175J.
R. Perry

SP 452J Current Issues in the Women's Movement

(Same subject as 21.917J)
Prereq.: —
U (2) HASS
3-0-9

See description under 21.917J.
L. Kampf, J. Seager

SP 455J Sex Roles: A Comparative Perspective

(Same subject as 21.531J)
Prereq.: —
U (1) HASS
3-0-9

See description under subject 21.531J.
J. E. Jackson

SP 456J The Contemporary Family

(Same subject as 21.530J)
Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

See description under subject 21.530J.
J. E. Jackson

SP 460J Psychology of Gender

(Same subject as 9.75J)
Prereq.: —
U (2) HASS **Next offered 1989-90**
3-0-6

See description under subject 9.75J.
S. E. Carey

SP 480J Women and Computers

(Same subject as STS 060J)
Prereq.: —
U (1) HASS
3-0-6

See description under subject STS 060J.
S. R. Turkle

SP 484J Reproductive Biology

(Same subject as 7.55J)
Prereq.: —
U (2) HASS
3-0-6

See subject description under 7.55J.
N. Hopkins, C. Whitbeck

See also: Women's section of 21.755 (Writing and Reading Short Stories, HUM-D).

STS

Science, Technology, and Society

General Undergraduate Subjects

History of Science and Technology

STS 001 Technology in American History (Revised Content)

(STS 300-301)
Prereq.: —
U (2) HASS-D/HUM-D
3-0-9

A survey of America's transition from a rural, agrarian, and artisan society to one of the world's leading industrial powers. Treats the emergence of industrial capitalism: the rise of the factory system, new forms of power, transport, and communication, the advent of the large industrial corporation, the social relations of production, and the hallmarks of science-based industry. Views technology as part of the larger culture and reveals innovation as a process consisting of a range of possibilities that are chosen or rejected according to social criteria of the time. Consult M. R. Smith.

STS 002 The Scientific Revolution

(STS 200)
Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

The Scientific Revolution and its later consequences during the Enlightenment. Origins of scientific thought in the West. Emergence of science as a new intellectual and social force in the late 16th and 17th centuries. Focuses on major scientists such as Copernicus, Kepler, Harvey, Galileo, and Newton, and philosophers such as Bacon, Descartes, and Leibniz.
K. R. Manning

STS 006 History of Nineteenth- and Twentieth-Century Science

(STS 201)
Prereq.: —
U (2) HUM-D **Next offered 1989-90**
3-0-9

Survey of the growth of the physical, chemical, and biological sciences since the end of the Enlightenment. Readings of selected works of major contributors to these fields with the intent to explore changing conceptions of natural phenomena, the nature of scientific fact, and the status of scientific knowledge. Other more general readings about the institutional context for scientific work, the relationship of science to industrialization, and how the concepts and ideas of science have significantly affected the development of Western culture.
L. L. Bucciarelli

STS 007J Ancient Cosmology

(STS 223J)
(Same subject as 21.930J)
Prereq.: —
U (1)
3-0-6

See description under subject 21.930J.
H. A. T. O. Reiche

STS 008 American Science Since the 1930s

(STS 210)
Prereq.: —
U (2) HUM-D
3-0-9

History of science and technology in the US from the 1930s Depression, through World War II, to the 1980s. Includes atomic bomb project, space race, computer revolution, environmental movement, biotechnology. Focuses on patterns of funding, international links, government-industry-academic relations, public understanding, response of the scientific community to new social responsibilities. Issues studied in relation to relevant social, economic, and political developments during the period.
C. Weiner

STS 009 Military Enterprise and Technological Change

(STS 323)
Prereq.: —
U (1) HUM-D
3-0-9

A history of the role of the military in promoting and developing new technologies (from medieval times to the present). Examines the design, deployment, and diffusion of new technologies; the behavioral/social problems that occurred with their introduction; and their influence on colonialism, industrialization, and warfare in the modern world.
L. Trilling

Social Study of Science and Technology

STS 011 Ideas of Power in American Literature, Art, and Culture (New)

Prereq.: —
U (1) HASS-D/HUM-D
3-0-9

Conflicting ideas of power in America as expressed by writers and artists from Shakespeare to Melville. Topics: the contrast between Old World and New World power as envisaged in Shakespeare's *The Tempest;* Benjamin Franklin, the protestant ethic and the spirit of capitalism; the conflict between Jeffersonian and Hamiltonian conceptions of industrial power; Tocqueville's and Emerson's concepts of the power of the individual in a democratic polity; the response of American landscape painters and writers to the onset of industrialism; and Melville's prevision of American global hegemony in *Moby Dick.*
L. Marx

STS 012J Engineers, Scientists, and Public Controversies (New — Context Subject)

(Same subject as 2.93J and 8.206J)
Prereq.: —
U (2)
3-0-9

Investigates the nature of controversies surrounding science and technology and the roles technical specialists play in their resolution. Students analyze the technical, social, political, and ethical context of public controversies through case studies documented by archival videotapes, readings, and testimony of guests. Cases may include the space shuttle accident, nuclear reactor safety, Star Wars, AIDS and other medical testing, and the release of environmental contaminants. May *not* count toward HASS Requirement.
C. Weiner, J. A. Fay, B. T. Feld

STS 013J Automation, Robotics, and Unemployment
(New — Context Subject)

(Same subject as 6.903J)
Prereq.: —
U (1)
3-0-9

Exploration of the short- and long-term effects of increased automation and the use of robots and computers on unemployment levels. Various aspects of the issue are examined through lectures, readings, and library research in a combined lecture and seminar mode. Term paper required. Latter half of semester is devoted to oral progress reports and group discussion of the papers. May *not* count toward HASS Requirement.
M. R. Smith, L. D. Smullin

STS 014J Life and Institutions of Science
(New — Context Subject)

(Same subject as 8.202J)
Prereq.: —
U (1)
3-0-9

An examination of the activity of science in three contexts: the personal experience context of "doing science"; the intellectual context of science as a way of thinking and knowing; and the social context in terms of the people who do science and the institution in which it is done, the nature and basis of support for science, and the uses society makes of it. The main focus is on today's world, but provides historical perspective, as well. Intended primarily for juniors and seniors in science and engineering. May *not* count toward HASS Requirement.
C. Kaysen, J. G. King

STS 018 Literature, Ideology, and Natıcnal Experience in the US

(STS 301J)
Prereq.: —
U (2)
3-0-9

Study of the interplay among imaginative literature, the prevailing ideologies, and collective experience in the US, emphasizing critical reading within a historical context. Readings chiefly drawn from classic American writers of the 19th century, but works from earlier and later periods included: F. Scott Fitzgerald, Franklin, Jefferson, Emerson, Tocqueville, Thoreau, Whitman, Hawthorne, Melville, Max Weber, and D. H. Lawrence.
L. Marx

STS 019 The Profession of Engineering

(STS 502)
Prereq.: —
U (2) HUM-D
3-0-9

Practice and dilemmas of the engineering profession. Analyzes the role of engineers in the conception, design, manufacture, and marketing of a sophisticated consumer product. Studies the history of some major industries (e.g., automobile, communications, biomedical, aerospace) in 20th-century US. Examines political, economic, social, and ethical implications. May be taken as a 12-unit HUM-D subject (lectures, recitations, three full term papers) or as an undergraduate seminar (lectures and three short papers).
L. Trilling

Advanced Undergraduate Subjects

History of Science and Technology

STS 021 Russian Science and Society

(STS 211)
Prereq.: —
U (2)
3-0-6

An introduction to the history of Russian and Soviet science. Topics: introduction of Western science to Russia, reception of Darwinism, influence of Marxism on Soviet scientific development, social and political context of Soviet science, role of dissidents in Soviet scientific life, and organizational and policy questions. Required readings in English; supplementary readings in Russian also available.
L. R. Graham

STS 022 The Social and Political Implications of Technology

(STS 306)
Prereq.: —
U (2) **Next offered 1989-90**
2-0-7

Examines the social and political implications of technology. Historical and contemporary studies are used to explore the interaction of technology with social and political values. Emphasis on how technological devices, structures, and systems influence the organization of society and the behavior of its members. Examples drawn from the technologies of war, transportation, communication, production, and reproduction.
L. R. Graham

STS 023J The Industrial Revolution: A Social and Cultural History (1750-1850)

(STS 315J)
(Same subject as 21.371J)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-9

See description under subject 21.371J.
B. Mazlish

STS 024 History of Modern Mathematics

(STS 220)
Prereq.: 18.02
U (2)
3-0-9

Development of algebra in the 16th century and of the calculus of Newton and Leibniz. Traces applications of calculus in the work of 18th-century mathematicians such as Euler, Lagrange, and Laplace. The development of rigorous analysis by Cauchy, Bolzano, Dedekind, and Weierstrass in the 19th century. Rise of abstract algebra, emergence of complex analysis, and development of set theory.
K. R. Manning

Social Study of Science and Technology

STS 051 Nuclear War: Threat and Avoidance

(STS 558)
Prereq.: —
U (2) HASS
3-0-6

Engineering School-Wide Elective Subject. Description given at end of this chapter on SWE page.
M. M. Miller, P. Morrison, G. W. Rathjens, J. P. Ruina

STS 052J American Television: A Cultural History

(STS 625J)
(Same subject as 21.032J)
Prereq.: One subject in Literature or Science, Technology, and Society
U (2) **Next offered 1989-90**
3-0-9

See description under subject 21.032J.
D. Thorburn

STS 053 Social and Political Implications of Science

(STS 206)
Prereq.: —
U (2) **Next offered 1989-90**
2-0-7

Historical and contemporary studies of the interaction of science with social and political values. Examines the use of scientific theories and findings to support conclusions about the proper organization of society and politics. Emphasis on how scientists have viewed the relationship of their scientific work to moral and ethical issues.
L. R. Graham

STS 054 Biotechnology and Society

(STS 408)
Prereq.: —
U (1) **Next offered 1989-90**
2-0-7

Examines the rapid growth of biotechnology; focuses on relation of academic scientists and universities to industrial and medical applications of research. Connects historical background with contemporary issues to view biotechnology in context of university education and research, funding of science, academic-industrial links, regulatory issues, roles and responsibilities of scientists, and public expectations and perceptions. Evaluates professional, institutional, and public-policy alternatives.
C. Weiner, M. L. Gefter

STS 055 Ethical Issues in Science and Engineering

(STS 410)
Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Ethical problems of scientists and engineers as students, employees, consultants, and advisors. Case studies of on-the-job ethical dilemmas and responses of technical professionals in such fields as weapons technology, nuclear energy, genetic engineering, chemical engineering, computer science, and biomedicine. Issues include social responsibility, conflicts of interest, whistleblowing, and the role of professional societies. Emphasis on class discussion. Student projects in fields of their interest.
C. Weiner

STS 056J Modern Times

(STS 500J)
(Same subject as 21.534J)
Prereq.: —
U (1)
3-0-6

See description under subject 21.534J.
Consult J. Howe.

STS 057J Cross-Cultural Studies of Scientific and Technological Institutions

(STS 231J)
(Same subject as 21.536J)
Prereq.: —
U (1) **Next offered 1989-90**
3-0-6

Analyzes several studies of laboratories and research groups around the world to investigate how culture impinges upon scientific activity. Evaluates key terms in the study of science and technology for their cultural assumptions by using those terms to explicate these laboratory studies. Discusses the design of ethnographic studies of scientific and technological laboratories. Consult K. Keniston.

STS 058J Industrialization and Cultural Change in Nineteenth-Century America

(STS 310J)
(Same subject as 21.433J)
Prereq.: —
U (2) **Next offered 1989-90**
3-0-6

A comparative study of six communities assessing the social dislocations and adjustments of an industrializing economy. The work ethic, craft customs, kinship ties, business attitudes, political ideologies, social institutions, and the growing speed and scale of mechanized production are among the factors treated. The goal is to understand why some communities entered the industrial age more easily than others. Students submit thematic essays addressing various aspects of industrialization and culture change.
Consult K. Keniston.

STS 059 Introduction to Cultural Criticism

(STS 603)
Prereq.: Permission of Instructor
U (2)
2-0-7

Examines modern concept of culture as it emerged during the Industrial Revolution and considers some of the theories and methods of analysis that have been developed around that concept. Among the basic theories considered are those associated with Marx, Emerson, Arnold, and Freud. Second half examines more recent elaborations of the culture concept in the work of such theorists as Panofsky, Burke, Benjamin, Marcuse, Foucault.
L. Marx

STS 060J Women and Computers

(STS 634J)
(Same subject as SP 430J)
Prereq.: —
U (1)
3-0-6

An exploration of factors that may limit or inhibit women's participation in the nascent computer culture. Includes math-phobia and machine-phobia, programming styles, personality styles and gender, social and psychological effects of office automation and computer work at home.
S. R. Turkle

Special Topics

STS 091 Reading Seminar in Humanities, Science, and Technology I

(STS 130J)
Prereq.: —
U (1)
2-0-7

STS 092 Reading Seminar in Humanities, Science, and Technology II

(STS 131J)
Prereq.: —
U (2)
2-0-7

Reading and discussion of major primary and secondary works that illustrate or examine the interactions of science, technology, and society.
Consult L. Trilling.

STS 093 Project Seminar on the Context of Research and Engineering Design

(STS 132J)
Prereq.: —
U (2)
3-0-6

Students draw upon their individual experience in a laboratory project, UROP project, or summer job to discuss broader aspects of scientific research and engineering design. Some common readings include *Zen and the Art of Motorcycle Maintenance* and *The Structure of Scientific Revolutions.* Consult L. Trilling.

STS 094 Undergraduate Research

(STS UR)
Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in the STS Program. For further information, consult the Academic Officer, L. Bucciarelli.

STS 095 Special Topics in Science, Technology, and Society

(STS 110, 111)
Prereq.: —
U (1, 2)
Arr.

For students who wish to pursue special studies or projects with a member of the program in Science, Technology, and Society.
Consult L. Bucciarelli.

Graduate Courses

History of Science and Technology

STS 101 Proseminar: History of Science and Technology

(STS 202)
Prereq.: —
G (1)
3-0-9

Intensive reading and analysis of key works in the history and historiography of science and technology. Aims at exploring similarities and differences between the two fields and at introducing students to basic interpretive issues, bibliographic sources, and professional standards. Topics change from year to year.
M. R. Smith

STS 102J Theories and Methods in the Study of History (New)

(Same subject as 21.498J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 21.498J.
B. Mazlish

STS 103J Russian Science and Society

(STS 212J)
(Same subject as 17.614J)
Prereq.: —
G (2)
3-0-9

An introduction to the history of Russian and Soviet science. Topics: introduction of Western science to Russia, reception of Darwinism, influence of Marxism on Soviet scientific development, social and political context of Soviet science, role of dissidents in Soviet scientific life, and organizational and policy questions. Required readings in English; supplementary readings in Russian also available.
L. R. Graham

STS 104 The Social and Political Implications of Technology

(STS 307)
Prereq.: —
G (2) **Next offered 1989-90**
2-0-10

Examines the social and political implications of technology. Historical and contemporary studies are used to explore the interaction of technology with social and political values. Emphasis on how technological devices, structures, and systems influence the organization of society and the behavior of its members. Examples drawn from the technologies of war, transportation, communication, production, and reproduction.
Consult K. Keniston.

STS 105J Social and Political Implications of Science

(STS 207J)
(Same subject as 17.336J)
Prereq.: Permission of Instructor
G (2) **Next offered 1989-90**
2-0-10

Historical and contemporary studies of the interaction of science with social and political values. Examines the use of scientific theories and findings to support conclusions about the proper organization of society and politics. Emphasis on how scientists have viewed the relationship of their scientific work to moral and ethical issues.
L. R. Graham

Social Study of Science and Technology

STS 501 Proseminar: Social Study of Science and Technology

Prereq.: —
G (1)
3-0-9

Intensive reading and analysis of key works in the theory and methods of the social study of science and technology. Aims at understanding the different questions and methods social scientists have posed and used in exploring how social context and norms influence the work of scientists and engineers. The relationship of the methods used to the questions raised is studied. Implications for the practice of science and engineering as well as for further scholarly study of that practice are explored.
S. R. Turkle

STS 502J Theory and Method in the Study of Social Institutions (New)

(Same subject as 21.570J)
Prereq.: —
G (2)
3-0-9

See description under subject 21.570J.
J. Howe, J. Jackson

STS 503J Special Topics in Science, Technology, and Public Policy (A)

(STS 460J)
(Same subject as 17.306J)
Prereq.: —
G (1)
3-0-9

See description under subject 17.306J.
H. Sapolsky, C. Kaysen, E. D. Skolnikoff

STS 504J Politics of Industrialization (A)

(STS 510J)
(Same subject as 17.154J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 17.154J.
C. F. Sabel

STS 505J Comparative Systems of Industrial Relations and Human Resource Development (A)

(STS 512J)
(Same subject as 14.674J, 15.674J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

See description under subject 15.674J.
R. J. Thomas, M. Piore

STS 506J Problems of Advanced Industrial Societies (A)

(STS 575J)
(Same subject as 17.166J)
Prereq.: 17.156J
G (2) **Next offered 1989-90**
3-0-9

See description under subject 17.166J.
S. Berger, M. J. Piore

STS 507 Introduction to Cultural Criticism

(STS 604)
Prereq.: Permission of Instructor
G (2)
2-0-7

Examines modern concept of culture as it emerged during the Industrial Revolution and considers some of the theories and methods of analysis that have been developed around that concept. Among the basic theories considered are those associated with Marx, Emerson, Arnold, and Freud. Second half examines more recent elaborations of the culture concept in the work of such theorists as Panofsky, Burke, Benjamin, Marcuse, Foucault.
L. Marx

STS 508J Political Psychology and Behavior (A)

(Same subject as 17.704J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 17.704J.
L. W. Pye, K. Keniston

STS 509J Politics, Technology, and Development in the Middle East (A)

(Same subject as 1.255J, 4.715J, 11.488J, 17.558J, 21.485J)
Prereq.: —
G (1)
3-0-9

See description under subject 17.558J.
N. Choucri, F. Moavenzadeh, R. Lewcock, K. Keniston

STS 510 Biotechnology and Society

(STS 409)
Prereq.: —
G (1) **Next offered 1989-90**
2-0-7

Examines the rapid growth of biotechnology; focuses on relation of academic scientists and universities to industrial and medical applications of research. Connects historical background with contemporary issues to view biotechnology in context of university education and research, funding of science, academic-industrial links, regulatory issues, roles and responsibilities of scientists, and public expectations and perceptions. Evaluates professional, institutional, and public-policy alternatives.
C. Weiner, M. L. Gefter

Research

STS 901 Advanced Topics in Science, Technology, and Society

(STS 120, 121)
Prereq.: —
G (1, 2)
Arr.

For students who wish to pursue special studies or projects at an advanced level with a member of the Program in Science, Technology, and Society. Consult M. R. Smith.

SWE Engineering School-Wide Electives

Computer Models of Physical and Engineering Systems

Offered under: 1.12, 2.101, 3.05, 10.11, 13.51, 16.008, 22.006
Prereq.: 18.02, 8.01
U (2) SD
3-0-9

Reduction of physical and engineering systems to idealized computer models; selection of numerical algorithms to explore model behavior. Linear and nonlinear equations, curve fitting, integration, finite differences, finite elements, initial-value problems. Examples drawn from fields primarily of interest to engineers. Extensive "hands-on" computing experience. Working knowledge of FORTRAN, PASCAL, or C expected.
S. Shyam Sunder

Nuclear War: Threat and Avoidance

Offered under: 6.934, 8.208, 13.91, 16.994, 17.465, 22.003, STS 051
Prereq.: —
U (2) HASS
3-0-6

The science, technology, politics, and strategic concepts relating to nuclear weapons and weapons systems. Nuclear weapons proliferation. The nuclear arms race. Successes and failures in nuclear arms control. New military technology and prospects for the future.
M. M. Miller, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

Introduction to Technology and Law

Offered under: 1.165, 2.998, 13.97, 16.792, 22.085
Prereq.: —
U (1) **Next Offered 1989-90**
3-0-9

Basic principles and functions of law, using cases and materials arising from scientific and technical issues. The legal process — private, judicial, legislative, and administrative lawmaking — and its impacts on engineers and scientists. How Federal and state governance grows as technology grows. How regulation controls and supports technology. Curbs on that power. How scientific and engineering conflicts are resolved inside a legal framework. Role of values in that process.
J. D. Nyhart

Inventions and Patents

Offered under: 3.172, 6.901, 16.673, 22.084
Prereq.: 14.02
U (1)
3-0-6

History of private and public rights in scientific discoveries and applied engineering, leading to the development of worldwide patent systems. The classes of invention protectable under the patent laws of the US, including the procedures in protecting inventions in the Patent Office and the courts. Reviews of past cases involving inventions and patents in a) the chemical process industry and medical field; b) devices in the mechanical, ocean exploration, civil, and/or aeronautical fields; c) the electrical and electronic areas, including key radio, solid-state, and computer inventions.
R. H. Rines

Management in Engineering

Offered under: 2.96, 6.930, 10.806, 13.52, 16.993, 22.002
Prereq.: —
U (1)
3-0-9

Introduction of engineering management in variety of settings: 1) role of engineering and its relationship to other functions, 2) managerial tools and concepts used in engineering organizations, 3) practice in handling short- and long-term problems, 4) career strategy and development. Topics: financial principles, management of innovation, engineering project planning and control, human factors, career planning, patents, and technical strategy. Case method of instruction emphasizes participation in class discussion. Juniors, seniors, or graduate students.
D. P. Hoult, H. S. Marcus

Optimal Design of Engineering Systems (Revised Content)

Offered under: 1.02, 6.940, 13.671
Prereq.: 1.00 or equivalent
U (1)
3-1-8

Introduction to mathematical programming for engineers. A review of unconstrained and constrained optimization including Kuhn-Tucker theory and convexity. Lagrangians and duality theory, linear programming and the simplex method, network models, integer and dynamic programming models. Examples and case studies taken from engineering problems. Use of educational computer packages in class and in homework assignments.
H. N. Psaraftis, Y. Sheffi, R. C. Larson

Probabilistic Models in Engineering (Revised Content)

Offered under 1.06, 6.939, 13.672, 16.793
Prereq.: 1.03 or 6.041 or 18.05
U (2)
3-2-7

Probabilistic analysis and modeling for engineers. Introductory stochastic processes and queueing theory, reliability of serial and parallel systems, fault-tree analysis, computer generations of random variates, Monte Carlo simulation, related statistical concepts. Examples from diverse fields of engineering. Computer-aided and/or field lab work.
A. R. Odoni, R. C. Larson, H. N. Psaraftis

Engineering Risk-Benefit Analysis (A)

Offered under: 1.155, 2.943, 3.577, 6.938, 10.816, 13.621, 16.794, 22.82
Prereq.: 18.02
G (2) **Next offered 1989-90**
3-0-6

Risk assessment, decision and cost-benefit analysis, and fault-tree methods for describing and making decisions about societal risks (nuclear reactors, dams, carcinogens, transport and disposal of hazardous materials) associated with large engineering projects. Balancing risks and benefits in situations involving human safety, environmental risks, and financial uncertainties. Presentations of major risk assessments and the public decision processes associated with them.
A. W. Drake, A. R. Odoni

Engineering Systems Analysis (A)

Offered under: 1.146, 2.192, 3.56, 13.62, 16.784, 22.821, TPP 21
Prereq.: Permission of Instructor
G (1)
3-0-6

Synthesis of analytic procedures for identification and selection of optimal systems. Review of economic framework for analysis. Systematic application of mathematical optimization to engineering problems. Evaluation procedures for single and multiattributed problems covering decision analysis in addition to standard procedures. Application of this material to real problems. Use of microcomputer packages and expert systems based in Project Athena.
R. de Neufville, J. P. Clark

Entrepreneurship

Offered under: 2.942, 3.566, 6.936, 10.801, 13.78,
16.672, 22.86
Prereq.: —
G (2)
4-0-5

Introduction to various issues faced by technical innovators/entrepreneurs. Topics include concept evaluation, patents and licensing, financing, marketing, business planning, accounting, and team building. Case studies are used. Term project required in which student ideas are developed into business plans. Open to undergraduates by permission of instructor.
W. C. Flowers

Nuclear Weapons and Arms Control: Technology and Policy Issues

Offered under: 6.932, 13.93, 16.995, 17.486, 22.811
Prereq.: —
G (1)
4-0-8

Reviews under weapons systems developments and efforts at arms control. Focuses on the interaction of technological factors with strategic concepts, intelligence assessments, and political judgment. Topics: nuclear weapons technology and effects, nuclear weapons proliferation, strategic defensive and offensive weapons, and analysis of current strategic arms programs. To the extent possible, experts who have played key roles in the topics covered are invited to give guest lectures.
G. W. Rathjens, J. P. Ruina

TPP Technology and Policy

TPP 11J Proseminar in Technology and Policy I (A)

(Same subject as 13.961J)
Prereq.: Permission of Instructor
G (1)
4-0-8

Explores the diversity of values that complicate the selection of policy: personal moral decisions, values inherent in various professions, and cultural differences. Case projects of increasing complexity explore these questions. Integral assessments of issues and processes. Emphasis on developing the participant's skills in making verbal and written presentations. Introductory core subject intended for TPP students. Permission of instructor required.
J. T. Kildow, R. D. Tabors, R. de Neufville

TPP 12J Proseminar in Technology and Policy II (A)

(Same subject as 13.962J)
Prereq.: TPP 11J
G (2)
3-0-6

Presents means to integrate the diversity of values held by participants in policy formation. First, builds on social welfare theory, to show how formal models of technology can be used to build consensus, identify points of contention, and form a basis for negotiation. Then, explores issues in negotiation, especially the importance of process in determining outcomes. Two major case projects, an analysis, and a negotiation, illustrate the material.
J. T. Kildow, R. Tabors, R. de Neufville

TPP 13J Leadership Seminar in Technology and Policy (A)

(Same subject as 1.980J)
Prereq.: Thesis Registration
G (2)
2-0-1

Exploration of the ways to create and lead effective change by 1) identifying a vision of improvements; 2) integrating professional analysis with the policy process; 3) enhancing personal skills; and 4) developing greater self-confidence. Presentations by experienced role models. One or more local field trips. Primarily intended for students in their final year of the Technology and Policy Program.
R. de Neufville

TPP 21 Engineering Systems Analysis (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

School-Wide Elective. Description given at the end of this chapter on SWE page.
R. de Neufville, J. P. Clark

TPP 22J The Policy-Making Process (A)

(Same subject as 17.220J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 17.220J.
M. Lipsky

TPP 32J Law, Technology, and Public Policy (A)

(Same subject as 3.576J)
Prereq.: —
G (2)
3-0-6

In-depth examination of the relationship between technology and the legal system. Five major areas discussed: 1) responses of the legal system to new social problems created by new or existing technology; 2) technological change in response to legal action; 3) changes in legal theory and practice resulting from new technical developments; 4) responses of the political system to proliferating technology; and 5) equity/market changes brought about by the law-technology interaction.
N. A. Ashford, C. Caldart

TPP 33J Environmental Law: Pollution Control (A)

(Same subject as 1.811J)
Prereq.: —
G (1)
3-0-6

See description under subject 1.811J.
N. A. Ashford, C. Caldart

TPP 34J Regulation of Chemical Toxins, Radiation, and Biotechnology (A)

(Same subject as 1.812J)
Prereq.: Prior law subjects or Permission of Instructor
G (2)
3-0-6

See description under subject 1.812J.
N. A. Ashford, D. B. Hattis, C. Caldart

TPP 35J Technology, Law, and the Working Environment (A)

(Same subject as 10.805J)
Prereq.: —
G (1)
3-0-6

See description under subject 10.805J.
N. A. Ashford, C. Caldart

TPP 51J Chemicals in the Environment: Fate and Transport (A)

(Same subject as 1.725J)
Prereq.: Permission of Instructor
G (1)
4-0-8

See description under subject 1.725J.
H. Hemond, D. Marks

TPP 52J Chemicals in the Environment: Sources and Control (A)

(Same subject as 10.72J)
Prereq.: Permission of Instructor
G (1)
3-0-6

See description under subject 10.72J.
J. R. Ehrenfeld, A. F. Sarofim

TPP 53J Chemicals in the Environment: Human Disease

(Same subject as 20.006J)
Prereq.: —
U (2)
3-0-6

See description under subject 20.006J.
W. G. Thilly

TPP 54J Chemicals in the Environment: Policy and Management

(Same subject as 11.363J, 15.650J)
Prereq.: —
G (2)
3-0-6

See description under subject 11.363J.
L. Susskind, J. R. Ehrenfeld, J. D. Nyhart

AS Aerospace Studies[1]

AS 11 The Air Force Today

Prereq.: —
U (1)
1-0-1

Examines the role of the US Air Force in the contemporary world by studying national security objectives and the uses of national power to achieve objectives. Includes background, mission and organization of the Air Force, and the functions of its forces. Emphasis is on the development of oral and written communications skills.
G. G. Nelson

AS 111 Leadership Laboratory

Prereq.: —
U (1) [P/F]
0-1-0

Introduction to the customs, traditions, and courtesies of the Air Force through seminars, guest speakers, and appropriate field trips.
B. K. Mazerski

AS 12 The Air Force Today

Prereq.: —
U (2)
1-0-1

Continues the study of the US Air Force and its role in the contemporary world. Includes Air Reserve Forces and other US Armed Forces. Compares and contrasts US and Soviet military power and capabilities.
G. G. Nelson

AS 121 Leadership Laboratory

Prereq.: AS 111
U (2) [P/F]
0-1-0

Continuation of AS 111 with emphasis on the role and responsibilities of an Air Force junior officer.
B. K. Mazerski

AS 21 US Air Power: Ascension to Prominence

Prereq.: —
U (1)
1-0-1

History of the development of air power, from its beginnings through World War II. Emphasis on the doctrine governing the employment of air power and how it developed. Also examines how technology has affected the growth of air power.
B. K. Mazerski

AS 211 Leadership Laboratory

Prereq.: AS 121
U (1) [P/F]
0-1-0

Emphasizes development of techniques used to direct and inform. Students are assigned leadership and management positions in the AS 111 programs described above.
B. K. Mazerski

AS 22 US Air Power: Key to Deterrence

Prereq.: Permission of Instructor
U (2)
1-0-1

Continues the history of air power since World War II, with emphasis on the US Air Force. Includes the role of air forces in conflicts, and the effect of space-age technology on air power. Also examines the employment of US air power in peaceful ways.
B. K. Mazerski

AS 221 Leadership Laboratory

Prereq.: AS 211
U (2) [P/F]
0-1-0

Continuation of AS 211. Adds a special program in preparation for Field Training.
B. K. Mazerski

AS 31 Management and Leadership

Prereq.: —
U (1)
3-0-3

Study of management and leadership from the point of view of the Air Force junior officer. The individual motivational and behavioral processes, leadership, communication, and group dynamics are covered to provide a foundation for the development of the junior officer's professional skills as an Air Force officer.
N. D. Larson

AS 311 Leadership Laboratory

Prereq.: AS 221
U (1) [P/F]
0-1-0

Supervisory practice and exercise of leadership functions in controlling and directing activities of the cadet corps. Development of leadership potential in a practical, supervised training laboratory.
B. K. Mazerski

AS 32 Management and Leadership

Prereq.: AS 31
U (2)
3-0-3

Continuation of AS 31, with special emphasis on the basic managerial processes involving decision making, utilizing analytical aids in planning, organizing, and controlling in a changing environment. Organizational and personal values, management of forces in change, organizational power, politics, and managerial strategy and tactics are discussed within the context of the military organization.
N. D. Larson

AS 321 Leadership Laboratory

Prereq.: AS 311
U (2) [P/F]
0-1-0

Continues AS 311 emphasis on supervisory and leadership skills. Emphasis on advantages of an Air Force career.
B. K. Mazerski

AS 41 American National Security: Policy and Process

Prereq.: —
U (1)
3-0-3

Examines the development of American National Security Policy through discussion of the various groups affecting policy. Investigates current issues of national and regional security issues. Emphasis on integration of current events into course topics. Students are asked to challenge current ideas on National Security Policy.
C. D. Barondes

AS 411 Leadership Laboratory

Prereq.: AS 321
U (1) [P/F]
0-1-0

Exercise of management functions in planning, supervising, and directing cadet corps activities. Acquire proficiency in military leadership skills.
B. K. Mazerski

[1] Aerospace Studies subjects are not for MIT credit.

AS 42 Issues For Today's Military

Prereq.: AS 41
U (2)
3-0-3

Study of selected issues that affect the military today. Topics include the laws of armed conflict, equal opportunity and training, women in combat, the military legal system, and the military as a profession. Emphasis on student presentation and initiative.
C. D. Barondes

AS 421 Leadership Laboratory

Prereq.: AS 411
U (2) [P/F]
0-1-0

Continues AS 411. Includes preparation for professional duties.
B. K. Mazerski

MS
Military Science[1]

MS 111 Introduction to ROTC and the Army

Prereq.: —
U (1)
1-2-1

Investigates the generalized employment of the US Army, starting with the formulation of US foreign policy and the uses of military power in diplomacy. Covers the development of Army combat power in terms of personnel and organization. Emphasizes knowledge of current military events and their impact on the nation, and written and verbal communications skills.
R. J. Gabriel

MS 121 The Fundamentals of Military Science

Prereq.: —
U (2)
1-2-1

Discusses interface between Active Army, National Guard, Reserves, and civilian work force; interservice and intra-alliance support. Examines organization and role of company-sized units; small-unit tactics and combined arms concepts. Specialties of soldiers are related to operational unit missions. Introduces principles of war and relates them to actual historical events.
R. J. Gabriel

MS 21 Instructional Methodology

Prereq.: —
U (1, 2)
2-0-1

Designed to provide the student with theoretical and practical experience in preparing and presenting effective oral presentations. Investigates the psychology and principles of learning, speech techniques, integration of audio-visual media, programmed instruction techniques, test and examination construction, and classroom management techniques. Every student required to deliver three oral presentations. The student is critiqued and evaluated by the instructor and other members of the seminar.
R. Bouchard

MS 211 Leadership

Prereq.: —
U (1)
1-2-1

Introduction to military leadership and management. Various leadership theories discussed, and an "Integrated Leadership Model" developed. Using this model, the class investigates the individual — his or her needs, goals, attitudes, and behavior; the group — its goals, structures, roles, and norms; and the leader — his or her style, behavior, needs, and goals. Topics such as interpersonal communications, motivation, and counseling discussed. Case studies are used to enhance classroom effort.
J. W. Connors

MS 221 Branches of the Army

Prereq.: —
U (2)
1-2-1

Acquaints students with the functional branches of the Army, to include their employment, initial entry positions, and the assignment patterns associated with each branch. Each functional branch studied in sufficient detail to provide a basic understanding. The Army's Officer Personnel Management System is introduced and addressed from the point of view of the individual officer's management of his or her own military experience.
J. W. Connors

MS 31 Small-Unit Tactics

Prereq.: —
U (1, 2)
2-0-1

Addresses the leadership of small units conducting conventional combat operations. Elements of terrain analysis and application to offensive, defensive, and retrograde operations discussed along with weather considerations and their impact on combat operations. Current organization and hardware associated with small tactical combined arms formations reviewed.
R. Bouchard

MS 311 Military Management

Prereq.: —
U (1)
1-2-1

Concerned with the integrated management of Army units and activities. The commander and the staff examined in detail, with emphasis on the various formal and informal methods used to acquire information, anticipate and forecast requirements, make decisions, implement those decisions, and supervise and evaluate the results. Nature and role of combat support activities discussed.
J. W. Connors

MS 321 Land Navigation

Prereq.: —
U (2)
1-2-1

Students acquire the ability to determine point locations accurate to within 10 meters, and learn the fundamentals of direction and distance determination both on a map and on the ground. Familiarizes students with the fundamentals of terrain analysis to include the ability to construct accurate terrain profiles. Familiarizes students with the techniques used in interpretation of aerial photographs, to include determination of scale and direction, and identification of objects on the ground.
R. Bouchard

MS 41 Military History

Prereq.: —
U (1, 2)
2-0-1

Examines the development of the US Army. Emphasizes giving the student a better understanding and perspective regarding the history of the US Army, the roles military professionals have played in shaping the US, and where the military profession fits into the society it serves. Equips the student with the tools necessary to analyze military operations at all levels, using historical methodology. Stimulates an interest in the study of military history leading the potential Army Officer to a mature, informed concept of his or her role as a leader in the US Army. An American Revolutionary War Battlefield study trip is included during IAP to meet the 45-hour Military History Requirement for Army ROTC Cadets.
R. T. Yongen

[1] Military Science subjects are not for MIT credit.

MS 411 Military Law and Administration

Prereq.: —
U (1)
1-2-1

Provides the military science student with an introduction to the United States Military Justice System. Develops historical and legal basis, as well as modern practical application, of Military Justice. Prepares student for a leadership position that inherently involves administration of discipline and justice. Includes discussion of practical aspects of small-unit administration.
E. D. Hammond

MS 421 Military Ethics and Professionalism

Prereq.: —
U (2)
1-2-1

Brings together material on two major topics: the military as a profession and morality and war. Stresses ethical dimensions of the military profession and juxtaposes positions of well-known scholars. Themes examined include the inextricable association of human values with the military profession and the resolution required when crucial military values are perceived as at odds with the parent society.
E. D. Hammond

NS Naval Science[1]

NS 11 Introduction to Naval Science

Prereq.: —
U (1)
2-0-1

General introduction to seapower and the naval service, covering an overview of the organization and historical development of the US Navy and its tactics and equipment. Covers the basic tenets of naval courtesy and customs, discipline, leadership, and ship construction, as well as the major challenges facing today's Naval officer.
W. S. Josephson

NS 12 Naval Ships Systems[2]

Prereq.: —
U (2)
3-0-3

Lecture series on technological fundamentals of applied and planned Naval Ships Systems from an engineering viewpoint. Topics: stability, propulsion, ship control, and compartmentation.
W. S. Josephson

NS 21 Naval Weapons Systems[2]

Prereq.: 18.02, 8.01
U (1)
3-0-3

Overview of the properties and behavior of electromagnetic radiation pertaining to maritime applications. Topics: communications, radar detection, electrooptics, tracking and guidance systems. Sonar and computer-controlled systems also discussed. Examples taken from systems found on naval ships and aircraft. Selected readings on naval weapons and fire control systems.
M. J. Quinlan

NS 22 Seapower and Maritime Affairs

Prereq.: —
U (2)
2-0-2

Exploration of the general concept and history of seapower (including the merchant marine and oceanographic research), the role of various warfare components of the Navy in supporting the Navy's mission, implementation of seapower as an instrument of national policy, and a comparative study of US and Soviet naval strategies.
M. J. Quinlan

NS 31 Coastal Piloting and Celestial Navigation[2]

Prereq.: —
U (1)
2-2-4

Comprehensive study of the theory, principles, and procedures of piloting and celestial navigation, including mathematics of navigation, practical work involving navigational instruments, slight reduction by *pro forma* and computerized methods, charts, publications, and voyage planning.
C. R. Souter

NS 32 Navigation and Naval Operations

Prereq.: —
U (2)
3-0-3

Comprehensive study of tactical and planning considerations relative to employment of naval forces, including communications, tactical formations and dispositions, relative motion, maneuvering board, and nautical rules of the road.
D. C. Hovda

NS 33 Evolution of Warfare

Prereq.: —
U (1) **Next offered 1989-90**
2-0-2

Study of warfare as an instrument of political action throughout modern history. Interrelationship with other components of statecraft stressed, as is the influence of economic, psychological, moral, political, and technological factors on strategic thought. Great leaders and military organizations of history examined to discover the ingredients of their successes.
M. C. Taylor

NS 34 Marine Corps Doctrine and Tactics

Prereq.: —
U (2)
2-0-2

Overview of general military subjects and concentration on Marine Corps small-unit tactics and leadership in preparation for Marine 1st Class cruise, "Bulldog." Covers the basic tenets of land navigation, the M16 rifle, offensive combat operations and orders, and leadership at the fire team and squad level. Stresses the development of individual leadership skills and self-confidence. Practical exercises in land navigation and tactics conducted at local military training areas.
M. C. Taylor

NS 41 Leadership and Management I

Prereq.: —
U (1)
2-0-4

Participative study of management theory. Includes the historical development of management; role of the manager; manager productivity; setting objectives and priorities; organization theory; the controlling function; performance appraisal; motivation; individual, interpersonal, and group behavior theory; leadership theory; communications; organizational change and development; decision making; the relationship between authority, responsibility, and accountability. The interface between technical and behavioral factors is included. The goal of the course is to better understand effective and efficient work with superiors, peers, and subordinates to optimize the use of scarce resources. Historical and hypothetical Naval Service scenarios are included.
J. G. Ward

NS 42 Leadership and Management II

Prereq.: —
U (2)
2-0-2

Gives the student a basic background in the duties and responsibilities of a junior division and watch officer; strong emphasis on the junior officer's responsibilities in the area of training, counseling, and career development. Student familiarized with equal opportunity programs and drug/alcohol rehabilitation programs. Principles of leadership reinforced through leadership case studies.
R. W. Sherer

NS 43 Evolution of Amphibious Warfare

Prereq.: —
U (2) **Not to be offered 1989-90**
2-0-4

Historical and tactical analysis of amphibious warfare. Seeks to define the concept, explore its doctrinal origins, and trace its evolution as an element of naval policy during the 20th century. Case study approach used to provide the prospective Marine Corps officer with the fundamentals of amphibious tactics.
M. C. Taylor

---

1 Naval Science subjects are not for MIT credit.

2 This subject is normally conducted in conjunction with an MIT accredited seminar. Any technical aspects of the subject matter of interest only to midshipmen are covered in separate NROTC sessions and field trips.

The Corporation

Howard W. Johnson
Honorary Chairman

David S. Saxon
Chairman

Paul E. Gray
President

Glenn P. Strehle
Vice President and Treasurer

Constantine B. Simonides
Vice President and Secretary[1]

Life Members

George P. Gardner
Advisory Director
PaineWebber Capital
Markets Inc.

Irenée du Pont, Jr.
Director
E. I. du Pont de Nemours &
Company, Inc.

John C. Haas
Chairman
William Penn Foundation

Paul M. Cook
Chairman of the Board
and Chief Executive Officer
Raychem Corporation

Ralph Landau
Listowel Incorporated

Carl M. Mueller
Retired Vice Chairman of the Board
Bankers Trust Company

Breene M. Kerr
Chairman and Chief Executive
Officer
Kerr Consolidated, Inc.

Louis W. Cabot
Chairman of the Board
The Brookings Institution

D. Reid Weedon, Jr.
Senior Vice President
Arthur D. Little, Inc.

Jerome B. Wiesner
President Emeritus and
Institute Professor Emeritus
Massachusetts Institute of
Technology

Kenneth H. Olsen
Director and President
Digital Equipment Corporation

W. Gerald Austen
Chief of the Surgical Services
Massachusetts General Hospital
Edward D. Churchill
Professor of Surgery
Harvard Medical School

Howard W. Johnson
Honorary Chairman of
the Corporation and
Special Faculty Professor Emeritus
Massachusetts Institute of Technology

Ellmore C. Patterson
Former Chairman of the Board
Morgan Guaranty Trust
Company of New York

Edward O. Vetter
President
Edward O. Vetter &
Associates, Inc.

Frank T. Cary
Retired Chairman of the Board
and Chief Executive Officer
IBM Corporation

Edward E. David, Jr.
President, EED, Inc.
Former President
Exxon Research and
Engineering Company

Norman B. Leventhal
Chairman
The Beacon Companies

Harold J. Muckley
Consultant

John S. Reed
Chairman
Citicorp/Citibank, N. A.

Jerry McAfee
Retired Chairman and
Chief Executive Officer
Gulf Oil Corporation

Yaichi Ayukawa
President
Techno-Venture Company, Ltd.

Joseph G. Gavin, Jr.
Former President and COO
Grumman Corporation

Mary Frances Wagley
Retired Educator

Members[2]

Donald J. Atwood (1989)
Vice Chairman of the Board of Directors
General Motors Corporation

E. R. Kane (1989)
Director and Former President
E. I. du Pont de Nemours &
Company, Inc.

Margaret E. Mahoney (1989)
President
The Commonwealth Fund

Robert L. Mitchell (1989)
Corporate Director
Retired Vice Chairman
Celanese Corporation

Arlene Frances Roane (1989)
Manager, Strategic Planning,
US WEST Service Link, Inc.

Mitchell W. Spellman (1989)
Dean for Medical Services and
Professor of Surgery, Harvard
Medical School
Executive Vice President
Harvard Medical Center
Harvard University

Raymond S. Stata (1989)
Chairman, President, and Co-Founder
Analog Devices, Inc.

Dolores Wharton (1989)
President
The Fund for Corporate Initiatives, Inc.

T. A. Wilson (1989)
Chairman Emeritus
The Boeing Company

Samuel W. Bodman (1990)
President and Chief Executive Officer
Cabot Corporation

Joan T. Bok (1990)
Chairman
New England Electric System

Colby H. Chandler (1990)
Chairman and Chief Executive Officer
Eastman Kodak Company

Karen L. Fulbright (1990)
Assistant Professor
New School for Social Research

Michael M. Koerner (1990)
President
Canada Overseas Investments, Ltd.

Christian J. Matthew (1990)
Retired Executive Vice President
St. Mary's Foundation

Robert J. Richardson (1990)
Retired President
Bell Canada Enterprises, Inc.

Robert A. Swanson (1990)
Chief Executive Officer
Genentech, Inc.

E. Milton Bevington (1991)
President and Chairman
Servidyne Incorporated

Ernest U. Buckman (1991)
Chairman
Oliver Realty/Grubb & Ellis

Alex W. Dreyfoos, Jr. (1991)
President
Photo Electronics Corporation

Joe F. Moore (1991)
President
Bonner & Moore Associates, Inc.

DuWayne J. Peterson, Jr. (1991)
Executive Vice President
Merrill Lynch & Co., Inc.

Charles H. Spaulding (1991)
President
Spaulding Investment Company

Sarah A. L. Tabler (1991)
Marketing Development Manager
ICAD, Inc.

Morris Tanenbaum (1991)
Vice Chairman of the Board
AT&T

E. Rudge Allen (1992)
Executive Vice President and
Director
Fayez Sarofim & Company

John K. Castle (1992)
Chairman and
Chief Executive Officer
Castle Harlan, Inc.

Robert B. Horton (1992)
Managing Director, BP
Chairman, BP America and
BP Nutrition

Walter J. Humann (1992)
Chairman, Executive Committee
Hunt Consolidated, Inc.

Shirley A. Jackson (1992)
Research Physicist
AT&T Bell Laboratories

F. Richard Meyer, III (1992)
Consultant in Corporate Mergers
and Acquisitions

Rita A. O'Brien (1992)
Consultant

Frank Press (1992)
President
National Academy of Sciences

1
Address correspondence to the Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

2
Terms expire on June 30 of the year indicated.

Robin M. Wagner (1992)
Graduate Student
Johns Hopkins School of Public Health

Robert A. Charpie (1993)
Chairman
Cabot Corporation

Herbert H. Dow (1993)
Vice President
The Dow Chemical Company

Margaret Coleman Haas (1993)
Consultant, Food Technology

David H. Koch (1993)
Director and Executive Vice President
Koch Industries, Inc.

Angus N. MacDonald (1993)
President
Angus MacDonald & Company, Inc.

H. DuBose Montgomery (1993)
General Partner
Menlo Ventures

Robert A. Muh (1993)
Independent Investment Banker

Megan J. Smith (1993)
Hyper Activist
Apple Computer Japan, Inc.

Frank S. Wyle (1993)
Founder Chairman
Wyle Laboratories

President of the Alumni Association

Emily V. Wade
Former President and Chairman
Boston Zoological Society

Representatives of the Commonwealth

His Excellency
Michael S. Dukakis
Governor

The Honorable
Edward F. Hennessey
Chief Justice of the Supreme
Judicial Court

Harold Raynolds, Jr.
Commissioner of Education

Life Members, Emeriti

Thomas D. Cabot
Chairman Emeritus
Cabot Corporation

Crawford H. Greenewalt
Honorary Chairman of
the Board
E. I. du Pont de Nemours &
Company, Inc.

William A. Coolidge
Retired Corporate Director

Robert C. Sprague
Honorary Chairman
Sprague Electric Company

James H. Doolittle
Corporate Director

Cecil H. Green
Honorary Director
Texas Instruments, Incorporated

H. W. McCurdy
Chairman of the Board
Puget Sound Dredging Company

Robert C. Gunness
Former Vice Chairman and President
Amoco Corporation

W. B. Murphy
Former President
Campbell Soup Company

Laurance S. Rockefeller
Honorary Chairman
Memorial Sloan-Kettering
Cancer Center

Julius A. Stratton
President Emeritus
Massachusetts Institute of Technology

Luis A. Ferré
Former Governor
The Commonwealth of Puerto Rico

Semon E. Knudsen
Retired Chairman
White Motor Corporation

Robert B. Semple
Former Chairman
BASF Wyandotte Corporation

J. Kenneth Jamieson
Former Chairman
Exxon Corporation

Joseph J. Snyder
Treasurer Emeritus
Massachusetts Institute of Technology

George W. Thorn
Physician-in-Chief Emeritus
Peter Bent Brigham Hospital
Hersey Professor of the Theory
and Practice of Physic Emeritus
Harvard Medical School
Chairman of the Board
of Trustees
Howard Hughes Medical Institute

Frank R. Milliken
Former Chairman and
Chief Executive Officer
Kennecott Copper Corporation

Gregory Smith
Former President and
General Manager
Eastman Gelatine Company

Richard L. Terrell
Retired Vice Chairman
General Motors Corporation

Kenneth J. Germeshausen
Founder and Past President and
Chairman
EG&G, Inc.

Office of the Chairman of the Corporation

David S. Saxon, Ph.D.
Chairman of the Corporation

Walter L. Milne, A.M.
Assistant to the Chairman

Ronald P. Suduiko, J.D.
Special Assistant
Government Relations

Kay Tamaribuchi, Ph.D.
Special Assistant
Resource Development

Jean B. Warren, A.A.
Administrative Assistant

Office of the Secretary of the Corporation

Elizabeth J. Whittaker, A.B.
Associate Secretary of the Corporation

Lois A. Graham, A.B.
Assistant to the Secretary for
Visiting Committees

Officers of the Faculty and Institute Professors

Officers of the Faculty

Paul Edward Gray, Sc.D.
President

Bernard J. Frieden, Ph.D.
Chair of the Faculty

Sallie W. Chisholm, Ph.D.
Associate Chair of the Faculty

Jack Philip Ruina, D.E.E.
Secretary of the Faculty

Institute Professors

Noam Avram Chomsky, Ph.D.
Mildred S. Dresselhaus, Ph.D.
Morris Halle, Ph.D.
Hermann A. Haus, Sc.D.
Francis Eugene Low, Ph.D.
Isadore Manual Singer, Ph.D.
Robert M. Solow, Ph.D., LL.D.
Edwin Herbert Land, LL.D., Sc.D. (Visiting)

Institute Professors, Emeriti

Manson Benedict, Ph.D.
Gordon Stanley Brown, Sc.D., D.Eng., Tekn.D.
Martin Julian Buerger, Ph.D.
Morris Cohen, Sc.D.
Harold Eugene Edgerton, Sc.D., D.Eng.
Herman Feshbach, Ph.D.
Gyorgy Kepes, M.A.
Chia-Chiao Lin, Ph.D.
Salvador Edward Luria, M.D., Sc.D.
Franco Modigliani, D.Jur., D.Soc.Sci., LL.D.
Philip Morrison, Ph.D.
Walle J. H. Nauta, M.D., Ph.D.
Walter A. Rosenblith, Ing.Rad., Sc.D., D.H.C.
Bruno Benedetto Rossi, Ph.D.
Paul Anthony Samuelson, Ph.D., LL.D., D.Litt., Sc.D.
Francis Otto Schmitt, Ph.D., Sc.D.
Nevin Stewart Scrimshaw, Ph.D., M.D., M.P.H.
Ascher Herman Shapiro, Sc.D.
Cyril Stanley Smith, Sc.D.
Arthur Robert Von Hippel, Ph.D.
Victor Frederick Weisskopf, Ph.D., Sc.D.
Jerome Bert Wiesner, Ph.D.

Special Faculty Professor, Emeritus

Howard Wesley Johnson, LL.D., L.H.D., Sc.D.

1988-89 James R. Killian, Jr., Faculty Achievement Award Lecturer

John S. Waugh, Ph.D.

1988-89 Harold E. Edgerton Award

(for recognition of excellence in teaching and research)

Peter C. Perdue, Ph.D.

Index

Absence due to Religious Beliefs, Institute Policy on Student 74
Academic Calendar 10
Academic Council 17
Academic Honesty 74
Academic Performance and Grades 71
Academic Performance, Committee on 70, 71
Academic Procedures and Institute Regulations 70
Academic Programs 9, 30
Academic Standards, Graduate 72
Academic Standards, Undergraduate 71
Accelerated Master of Science in Political Science 206
Accreditation Board for Engineering and Technology 120, 125, 132, 139, 140, 150, 157, 165, 167, 177, 178
Acoustics 81
Acoustics and Vibrations Laboratory 165
Activities, Campus 20
Administration of Institute Policy 77
Admission, Application for 50, 62
Admissions, College Transfer 52
Admissions, Deferred 50
Admissions for OSP Staff, Graduate School 63
Admissions, Foreign Graduate. See International Graduate Admissions
Admissions, Foreign Undergraduate. See International Undergraduate Admissions
Admissions, Freshman 50
Admissions, Regular Graduate 62
Admissions, Special Student 53, 63
Advanced Construction Materials Laboratory 144
Advanced Credit 52
Advanced Degrees, Undergraduate Requirements for 62
Advanced Engineering Study, Center for 83
Advanced Placement 50
Advanced Standing Examinations 34
Advanced Study Program 83
Advanced Visual Studies, Center for 84, 105
Advising and Counseling 26
Advising and Education, Preprofessional 27
Aeroelasticity, Structures, Materials, and 128
Aeronautical and Astronautical Systems 128
Aeronautics and Astronautics, Bachelor of Science in 124
Aeronautics and Astronautics, Cooperative Program in 126
Aeronautics and Astronautics, Department of 122
Aeronautics and Astronautics Divisions of Instruction and Research Laboratories 127
Aeronautics and Astronautics, Doctor of Philosophy and Doctor of Science in 129
Aeronautics and Astronautics, Engineer in 129
Aeronautics and Astronautics, Interdisciplinary Programs in 130
Aeronautics and Astronautics, Master of Science in 129
Aeronautics and Astronautics, Subjects in 145D
Aerospace Studies, Subjects in 238D
Aga Khan Program for Islamic Architecture 104, 111
Air Force ROTC Program 36
Alcohol, Policy Statement on the Use of 75
Alpha Phi Omega 21
Alumnae, Association of MIT 17
Alumni Association 17
Alumni Fund 17
Alumni Placement 27
American Studies 183
Analytical Mechanics 144
Ancient and Medieval Studies 184
Ancient Technology Program, Archaeology and 86
Anthropology and Archaeology 86, 190
Anthropology/Archaeology, Minor Program in 190
Anthropology/Archaeology, Subjects in 199D
Application for Admission 50, 62
Applications for Financial Aid 52, 66
Applied Biological Sciences, Doctor of Philosophy and Doctor of Science 245
Applied Biological Sciences, Master of Science 245
Applied Biological Sciences, Program in 245
Applied Biological Sciences, Subjects in 179D
Applied Biology 223
Applied Chemistry 134
Applied Mathematics 235, 239
Applied Physics Research 97
Aquatic Science and Environmental Engineering 145
Archaeology and Ancient Technology Program 86
Archaeology and Anthropology 44, 86, 190
Archaeology and Ethnology, Center for Materials Research in 86
Architectural Design 108
Architecture and Planning, Laboratory of 93, 105
Architecture and Planning, School of 104
Architecture, Art, and Environmental Studies, Doctor of Philosophy in 111
Architecture, Bachelor of Science in 109
Architecture, Department of 108
Architecture, Master of 59, 110
Architecture, Simultaneous Master's Degrees in City Planning and 117
Architecture Studies 108
Architecture Studies, Master of Science in 110
Architecture, Subjects in 34D
Army ROTC Program 37
Art and Architecture, History, Theory, and Criticism of 108
Art and Design, Bachelor of Science in 108
Artificial Intelligence Laboratory 81
Arts at MIT, Council for the 13
Arts, Humanities, and Social Sciences Requirement 42
Ashdown House, Avery Allen 25
Assistantships, Teaching and Research 67
Association of Student Activities 20
Astronautical Systems, Aeronautical and 128
Astronomy and Astrophysics 81
Astronomy and Astrophysics, Observatories and Facilities 81
Astrophysics 244
Athena, Project 13
Athletic Facilities 15, 21
Athletics 20
Athletics Center 15
Atmospheric, and Planetary Sciences, Department of Earth, 229
Avionics Option 125

Babysitting 27
Bachelor of Science in Aeronautics and Astronautics 124
Bachelor of Science in Architecture 109
Bachelor of Science in Art and Design 108
Bachelor of Science in Chemical Engineering 133
Bachelor of Science in Chemistry 227
Bachelor of Science in Civil Engineering 139
Bachelor of Science in Cognitive Science 252
Bachelor of Science in Computer Science and Engineering 151
Bachelor of Science in Earth, Atmospheric, and Planetary Sciences 230
Bachelor of Science in Economics 187
Bachelor of Science in Electrical Engineering 150
Bachelor of Science in Humanities 196
Bachelor of Science in Humanities and Engineering 197
Bachelor of Science in Humanities and Science 197
Bachelor of Science in Life Sciences 223
Bachelor of Science in Management Science 216
Bachelor of Science in Materials Science and Engineering 157
Bachelor of Science in Mathematics 235
Bachelor of Science in Mathematics with Computer Science 237
Bachelor of Science in Mechanical Engineering 165
Bachelor of Science in Nuclear Engineering 172
Bachelor of Science in Ocean Engineering, in Naval Architecture and Marine Engineering, or Without Designation 179
Bachelor of Science in Philosophy 201
Bachelor of Science in Physics 242
Bachelor of Science in Planning 114
Bachelor of Science in Political Science 205
Bachelor of Science in Unspecified Degree Programs for Interdisciplinary Study 101
Bachelor of Science in Urban Studies. See Bachelor of Science in Planning
Bachelor's and Master's Degree Program, Combined 167
Bachelor's and Master's Degrees, Simultaneous Award of 60
Bachelor's Degrees, Program for Two 34
Bates Linear Accelerator Center 92
Biochemistry 225
Bioelectrical Engineering Option 151
Biological Information Processing, Center for 84
Biological Oceanography 225
Biology, Applied 223
Biology, Department of 222
Biology, Doctor of Philosophy in 225
Biology, Subjects in 67D
Biomechanics and Human Rehabilitation Laboratory. See Newman Laboratory for Biomechanics and Human Rehabilitation
Biomedical Engineering 82, 128, 130, 134, 164
Biomedical Engineering at MIT, Summary of Graduate Degree Opportunities in 82
Biomedical Engineering, Doctor of Science or Doctor of Philosophy in 82
Biomedical Engineering, Interdisciplinary Ph.D. Program in 130
Biomedical Research, Whitehead Institute for 101
Biomedical Sciences Program, Doctor of Medicine in 82, 254
Biophysical Chemistry and Molecular Structure 225
Biotechnology Process Engineering Center 83
Bitter National Magnet Laboratory 83
Black Student Union, MIT 21
Blue Cross and Blue Shield Hospital Insurance, MIT Student 27
Board and Room 24, 53, 64
Boston Environment 16
Boston University 61
Brain and Cognitive Sciences, Department of 250
Brain and Cognitive Sciences, Doctor of Philosophy in 253
Brain and Cognitive Sciences, Doctoral Program in 248
Brain and Cognitive Sciences, Subjects in 79D
Brandeis University 61
Building Technology 110
Bursary Payment Plan 54, 65

Calculus Requirement 41
Calendar, Academic 10
Campus 14
Campus Activities 20
Campus Tours 15
Cancer Research, Center for 84
Career Services and Preprofessional Advising, Office of 27, 35
Cars 77
Cell Biology 225
Center, Bates Linear Accelerator 92
Center for Advanced Engineering Study 83
Center for Advanced Visual Studies 84, 105
Center for Biological Information Processing 84
Center for Cancer Research 84
Center for Cognitive Science 85
Center for Computational Research in Economics and Management Science 85
Center for Construction Research and Education 145
Center for Energy Policy Research 89
Center for Environmental Health Sciences 85
Center for Information Systems Research 85
Center for International Studies 86
Center for Materials Research in Archaeology and Ethnology 86
Center for Materials Science and Engineering 87
Center for Meteorology and Physical Oceanography 233
Center for Real Estate Development 87, 105
Center for Space Research 87
Center for Technology, Policy, and Industrial Development 87
Center for Theoretical Physics 244
Center for Transportation Studies 88, 144
Center, Materials Processing 94
Center, Plasma Fusion 97
Center, Statistics 99
Ceramics, Master of Science in 160
Chapel 21
Charges for Late Changes in Registration 54, 65
Cheating. See Academic Honesty
Chemical Engineer 136
Chemical Engineering, Bachelor of Science in 132
Chemical Engineering, Department of 132
Chemical Engineering, Doctor of Philosophy and Doctor of Science in 136
Chemical Engineering, Master of Science in 135
Chemical Engineering Practice, Master of Science in 135
Chemical Engineering Practice, School of 135
Chemical Engineering, Subjects in 84D
Chemical Oceanography 255
Chemistry, Applied 134
Chemistry, Bachelor of Science in 227
Chemistry, Department of 226
Chemistry, Doctor of Philosophy and Doctor of Science in 228
Chemistry, Master of Science in 228
Chemistry Requirement 40
Chemistry, Subjects in 48D
Child Care Services 27
City Planning and Architecture, Simultaneous Master's Degrees in 117
City Planning and Real Estate Development, Simultaneous Master's Degrees in 118
City Planning and Transportation, Simultaneous Master's Degrees in 117
City Planning, Master in 59, 117
Civil Engineer 143
Civil Engineering, Bachelor of Science in 139
Civil Engineering, Department of 137
Civil Engineering, Doctor of Philosophy and Doctor of Science in 143
Civil Engineering, Master of Science in 143
Civil Engineering, Subjects in 2D
Clinical Research Center 88
Clubs. See Special Interest Groups
Coed Fraternity Residences 24
Cognitive Science, Bachelor of Science in 252
Cognitive Science Programs 85
College Transfer Admissions 52
College Work-Study 55
Combined Doctor of Medicine-Doctor of Philosophy Program in the Harvard-MIT Division of Health Sciences and Technology 254
Combustion and Propulsion Laboratory 165
Committee, Nominations 20
Committee on Academic Performance 70, 71
Committee on Discipline 75
Committee on Graduate School Policy 20, 58, 72
Committee on Privacy 77
Committee on the Visual Arts 22
Committee, Student Center 20
Communication Science and Systems 92
Community Development, Housing and 117
Community Fellows Program 118
Community Planning, Neighborhood and 114
Community Players, MIT 22
Compton Gallery, Margaret Hutchinson 22
Computational Research in Economics and Management Science, Center for 83, 85
Computer-Aided Engineering 144
Computer and Information Systems 92
Computer Resource Laboratory 105
Computer Science and Engineering, Bachelor of Science in 15
Computer Science, Laboratory for 91
Computer Science, Mathematics and 237
Computers, and Control, Systems, 164
Concentration, Fields of 42
Concentrations in Literature 193
Concourse Program 31, 88
Conservation, Energy Conversion and 164
Constructed Facilities Division 143
Construction Engineering and Management 145
Construction Research and Education, Center for 145
Context Subjects 32
Control, Instrumentation, Guidance, and 128
Control, Systems, Computers, and 164
Cooperative Living 24
Cooperative Program in Aeronautics and Astronautics 126
Cooperative Programs, with other Institutions 38, 61
Cooperative Programs 53, 64
Cooperative Writing Programs 195
Corporation 17, 502
Costs for Graduate Students 64
Costs for Undergraduate Students 53
Council for the Arts at MIT 13
Counseling and Advising 26
Course VI-A, Internship Program 152
Courses 9, 30
Credit Limit for Freshmen 32
Credits. See Subject Credits and Designations
Cross Registration at Other Institutions 38, 61
Cryogenic Engineering Laboratory 165

Dance 21
Dance Workshop, MIT 21
Day Care. See Child Care Services
Dean of the Graduate School 17
Dean for Undergraduate Education 17
Decision Systems, Laboratory for Information and 92
Deferred Admissions 50
Degree Programs, Interdepartmental 58, 80
Degrees, Doctoral 60
Degrees, Double 34, 59, 60
Degrees, Engineer's 60
Degrees, Master's 59
Department of Aeronautics and Astronautics 122
Department of Architecture 107
Department of Biology 222
Department of Brain and Cognitive Sciences 250
Department of Chemical Engineering 131
Department of Chemistry 226
Department of Civil Engineering 137
Department of Earth, Atmospheric, and Planetary Sciences 229
Department of Economics 186
Department of Electrical Engineering and Computer Science 147
Department of Humanities 190
Department of Linguistics and Philosophy 200
Department of Materials Science and Engineering 155
Department of Mathematics 234
Department of Mechanical Engineering 162
Department of Nuclear Engineering 170
Department of Ocean Engineering 176
Department of Physics 240
Department of Political Science 204
Department of Urban Studies and Planning 112
Departmental Programs 9, 30, 103
Departmental Degree Programs and Requirements 103
Design and Development 116
Design, Environmental 110
Design for Islamic Cultures 111
Developing Countries, Urban and Regional Planning in 115
Development, Master of Science in Real Estate 87
Development Program, Technology and 99
Development, Real Estate 116
Developmental Biology 225
Dining Plans 23
Disciplinary Committee Procedures, Statement of 75
Discipline, Committee on 75
Disclosure of Information about Students 76
Distribution Subjects 43
Division of Health Sciences and Technology, Harvard-MIT 254
Division of Nuclei and Particles 244
Divisions, Laboratories, and Special Programs, Civil Engineering 143
Doctoral Degrees 60
Doctoral Program in Brain and Cognitive Sciences 248
Doctoral Program in Medical Engineering and Medical Physics 254
Doctoral Program in Radiological Science 248
Doctoral Program in Toxicology 248
Doctor of Medicine-Doctor of Philosophy, Combined Program in the Harvard-MIT Division of Health Sciences and Technology 254
Doctor of Medicine in Biomedical Sciences Program 82, 254
Doctor of Philosophy and Doctor of Science, Aeronautics and Astronautics 129
Doctor of Philosophy and Doctor of Science, Applied Biological Sciences 245
Doctor of Philosophy and Doctor of Science, Chemical Engineering 136

Doctor of Philosophy and Doctor of Science, Chemistry 228
Doctor of Philosophy and Doctor of Science, Civil Engineering 143
Doctor of Philosophy and Doctor of Science, Earth, Atmospheric, and Planetary Sciences 232
Doctor of Philosophy and Doctor of Science, Electrical Engineering and Computer Science 154
Doctor of Philosophy and Doctor of Science, Materials Science and Engineering 160
Doctor of Philosophy and Doctor of Science, Mathematics 239
Doctor of Philosophy and Doctor of Science, Mechanical Engineering 169
Doctor of Philosophy and Doctor of Science, Nuclear Engineering 174
Doctor of Philosophy and Doctor of Science, Ocean Engineering 179
Doctor of Philosophy and Doctor of Science, Oceanography 232
Doctor of Philosophy and Doctor of Science, Physics 244
Doctor of Philosophy, Architecture, Art, and Environmental Studies 111
Doctor of Philosophy, Biology 225
Doctor of Philosophy, Brain and Cognitive Sciences 253
Doctor of Philosophy, Economics 189
Doctor of Philosophy, Economics and Urban Studies 89
Doctor of Philosophy, Linguistics 203
Doctor of Philosophy, Management 218
Doctor of Philosophy, Mineral Resources Engineering and Management 95
Doctor of Philosophy, Operations Research 96
Doctor of Philosophy, Philosophy 203
Doctor of Philosophy, Political Science 206
Doctor of Philosophy, Urban Studies and Planning 118
Doctor of Science or Doctor of Philosophy in Biomedical Engineering 82
Domestic Year Away 39
Dormitory Council 20
Double Competence in Humanities/Social Science and Science/Engineering, Programs for 98
Double Degrees 34, 59, 60
Drama Program 184
Dramashop 22
Draper Laboratory 89

Early Action in Admissions 51
Earth and Planetary Sciences, in Meteorology, or Oceanography, Master of Science in 232
Earth, Atmospheric, and Planetary Sciences, Bachelor of Science in 230
Earth, Atmospheric, and Planetary Sciences, Department of 229
Earth, Atmospheric, and Planetary Sciences, Doctor of Philosophy and Doctor of Science in 232
Earth, Atmospheric, and Planetary Sciences, Subjects in 101D
Earth Resources Laboratory 233
Eastgate 25
Economics and Urban Studies, Doctor of Philosophy in 89
Economics, Bachelor of Science in 187
Economics, Department of 186
Economics, Doctor of Philosophy in 189
Economics, Master of Science in 189
Economics, Minor Program in 187
Economics, Subjects in 119D
Education, Prelaw 35
Education, Premedical 35
Education Studies 35
Educational Policy, Student Committee on 20
Educational Resources 12
Elective Subjects 45
Electives 34
Electives in Engineering, School-Wide 121, 235D
Electrical Engineer 154
Electrical Engineering and Computer Science, Department of 147
Electrical Engineering and Computer Science, Doctor of Philosophy and Doctor of Science in 154
Electrical Engineering and Computer Science, Master of Science in 154
Electrical Engineering and Computer Science, Subjects in 51D
Electrical Engineering, Bachelor of Science in 150
Electrical Engineering, Physics with 243
Electromagnetic and Electronic Systems, Laboratory for 91
Electronic Materials 160
Electronics, Research Laboratory of 98
Electronic Systems, Laboratory for Electromagnetic and 91
Employment and Job Opportunities 27, 34, 54, 63, 67
End-of-Term Regulations 73
Energy Conversion and Conservation 164
Energy Conversion, Propulsion and 128
Energy Laboratory 89
Energy Policy Research, Center for 89
Energy Study and Research 89
Engineer, Aeronautics and Astronautics 129
Engineer, Chemical 136
Engineer, Civil 143
Engineer, Electrical 154
Engineer, Environmental 135, 143
Engineer, Materials 136, 160
Engineer, Mechanical 169
Engineer, Metallurgical 160
Engineer, Nuclear 174
Engineer, Ocean 180
Engineering and Technology, Accreditation Board for 120, 125, 132, 139, 140, 150, 157, 165, 167, 177, 178
Engineering, Degree Programs in 120
Engineering Internship Program 120, 126, 139, 152, 159, 167
Engineering, Master of Science in Management and 161, 218
Engineering, Naval Construction and 180
Engineering, Power 97
Engineering Risk Assessment 144
Engineering, School of 119
Engineering, School-Wide Electives in 121, 235D
Engineering Systems and Computation 140
Engineer's Degrees 60
English as a Second Language. See Subjects in Foreign Languages and Literatures
English Competency of International Students 51
English. See Literature
Entrance Examinations 51, 62
Entrance Examinations for International Applicants 51, 63
Environmental Design 110
Environmental Engineer 135, 143
Environmental Engineering 164
Environmental Engineering, Aquatic Science and 145
Environmental Engineering, Water Resources and 145
Environmental Health Sciences, Center for 85
Environmental Planning 113
Environmental Planning and Policy 117
ESG (Experimental Study Group) 31, 90
Ethnology and Archaeology, Center for Materials Research in 86
Evening Classes 12
Examinations, Final 71
Examinations for Advanced Standing 34
Examinations for Entrance 51, 62
Exchange Programs 38, 61
Executive Education in Management, Programs for 219
Executive Education Program, Health Management Option 219
Experimental Study Group. See ESG
Extracurricular Activities. See Special Interest Groups

Faculty and Staff, Personal Files of 77
Faculty Council 17
Faculty Policy Committee 17
Fees and Tuition 53, 64
Fees, Miscellaneous 54, 65
Fellowships 66
Fibers and Polymers Laboratories 165
Fields of Concentration 42
Fieldwork and Internships in Urban Studies 117
Fifth-Year Programs 231
Film and Media Studies 184
Films, Lectures, and Seminars 21
Final Examinations 71
Finance Board 20
Financial Aid, Applications for 52, 66
Financial Aid 54, 66
Flight Transportation 130
Fluids, Mechanics and Physics of 127
Fluid Mechanics Laboratory 165
Food and Nutrition Program, International 90
Foreign Graduate Admissions. See International Graduate Admissions
Foreign Languages and Literatures 191
Foreign Languages and Literatures, Minor Programs in 191
Foreign Languages and Literatures, Subjects in 185D
Foreign Undergraduate Admissions. See International Undergraduate Admissions
Fossil Energy Engineering, Fuel and 135
Fraternities, Sororities, and Independent Living Groups 24
French. See Subjects in Foreign Languages and Literatures
Freshman Admissions 50
Freshman Advisor Seminars, Undergraduate Seminars and 34, 101
Freshman Credit Limit 32
Freshman Grading 32
Freshman Handbook 32
Freshman Year 30
Fuel and Fossil Energy Engineering 135
Fusion Systems 97
Fusion Technology and Engineering 97

Gallery, Margaret Hutchinson Compton 22
Gays at MIT (GAMIT) 21
General Institute Requirements 40
General Requirements for Graduate Degrees 59
Genetics/Microbiology 225
Geotechnical Engineering 143
Geotechnical Engineering Research Laboratory 144
German. See Subjects in Foreign Languages and Literatures
Government, Graduate Student 20

Government, Undergraduate Student 20
Grade Reports and Transcripts 71
Grades 72
Grading, Freshman 32
Grading, Pass/No Record 32
Graduate Academic Standards 72
Graduate Admissions, Foreign. See International Graduate Admissions
Graduate Admissions, Regular 62
Graduate Degrees, General Requirements for 59
Graduate Education at MIT 58
Graduate Examinations 62
Graduate Interdepartmental Opportunities 80
Graduate Living Costs 65
Graduate School, Dean of 17
Graduate School, Organization of the 58
Graduate School Policy, Committee on 20, 58, 72
Graduate Single Student Housing 25
Graduate Student Government 20
Graduate Student Council 20
Graduate Student Status for Research Staff Members 63
Graduate Students, Costs for 64
Graduate Students, Special 63
Grants, Loans, and Employment 54
Green Hall 25
Guidance, and Control, Instrumentation, 128

Harassment, Policy on 74
Harrison Spectroscopy Laboratory, George R. 98
Hart Nautical Collections 22
Harvard-MIT Division of Health Sciences and Technology 254
Harvard-MIT Division of Health Sciences and Technology, Combined Doctor of Medicine-Doctor of Philosophy Program in 254
Harvard University 39, 61
Haystack Radio Observatory 82
Hazing, Institute Policy on 72
Health Management Option 219
Health Program, Student 26
Health Sciences and Technology 90
Health Sciences and Technology, Combined Doctor of Medicine-Doctor of Philosophy in the Harvard-MIT Division of 254
Health Sciences and Technology, Harvard-MIT Division of 254
Health Sciences and Technology, Master of Science in 254
Health Sciences and Technology, Subjects in 223D
Health Sciences, Technology, and Management, Whitaker College of 247
Health Service Fee 53, 64
Health Services. See Medical Services
Heat Transfer Laboratory 165
Historical Collections, MIT Museum and 22
History 192
History, Minor Program in 192
History of MIT 8
History, Subjects in 193D
History, Theory, and Criticism of Art and Architecture 108
Hospital Insurance, MIT Student Blue Cross and Blue Shield 27
Housing 23
Housing and Community Development 117
Housing and Settlement Design 110
Humanities and Engineering 98, 197
Humanities and Engineering, Bachelor of Science in 197
Humanities and Science 98, 197
Humanities and Science, Bachelor of Science in 197
Humanities and Social Science, School of 182
Humanities and Social Science, Minor in 33
Humanities, Arts, and Social Sciences Requirement 42
Humanities, Bachelor of Science in 196
Humanities, Department of 190
Humanities distribution requirements for continuing students 44
Humanities distribution requirements for entering students 43
Humanities, Interdisciplinary Programs in 90
Humanities and Social Sciences, Special and Interdisciplinary Programs in 183
Humanities/Social Science and Science/Engineering, Programs for Double Competence in 98
Humanities, Subjects in 181D
Human Rehabilitation and Biomechanics, Eric P. and Evelyn E. Newman Laboratory for 165
Hydrodynamics, Coastal, and Oceanographic Engineering 145
Hydrodynamics, Ralph M. Parsons Laboratory for Water Resources and 145
Hydrology and Water Resource Systems 145

IAP (Independent Activities Period) 10, 48, 58
Immunology 225
Independent Living Groups, Fraternities, Sororities and 24
Industrial Development, Center for Technology, Policy, and 87
Industrial Liaison Program 17
Information about Students, Disclosure of 76
Information and Decision Systems, Laboratory for 92
Information Systems 12
Information Systems Research, Center for 85
Institute Houses 23
Institute, Organization of the 17
Institute Policy, Administration of 77
Institute Policy on Hazing 74
Institute Policy on Racist Behavior 74
Institute Policy on Student Absence Due to Religious Beliefs 74
Institute Regulations, Academic Procedures and 70
Institute Regulations, Policies and Procedures 74
Institute Requirements, General 40
Instrumentation, Guidance, and Control 128
Integrated Studies Program 31, 90, 184
Intelligent Engineering Systems Laboratory 144
Intercollegiate Athletics 20
Interdepartmental Degree Programs 58, 80
Interdepartmental Graduate Opportunities 80
Interdepartmental Organizations and Research Facilities 80
Interdepartmental Study and Research 80
Interdisciplinary Ph.D. Program in Biomedical Engineering 130
Interdisciplinary Programs in Aeronautics and Astronautics 130
Interdisciplinary Programs in Humanities 90
Interdisciplinary Research Opportunities for Undergraduates. See UROP
Interdisciplinary Study, Unspecified Degree Programs 101
Interfraternity Conference 20, 24
International Food and Nutrition Program 90
International Graduate Admissions 63
International Students' Association 20
International Studies, Center for 86
International Undergraduate Admissions 51
Internship Program, Course VI-A 152
Internship Program, Engineering 120, 126, 139, 152, 159, 167
Internships and Fieldwork in Urban Studies 117
Interphase, Project 50
Interview 50
Intramural Athletic Program 21
Islamic Architecture, Aga Khan Program for 104, 111
Islamic Cultures, Design for 111

January Independent Activities Period 10, 48, 58
Job Opportunities, Employment and 27, 34, 54, 63, 67
Joint Program in Oceanography and Oceanographic Engineering with Woods Hole Oceanographic Institution 61, 96, 136, 146, 154, 180, 189, 225, 232, 255
Junior-Senior Pass/Fail Option 34
Junior Year Abroad 38

Laboratories, Fibers and Polymers 165
Laboratory, Acoustics and Vibrations 165
Laboratory, Advanced Construction Materials 144
Laboratory, Artificial Intelligence 81
Laboratory, Bitter National Magnet 83
Laboratory, Combustion and Propulsion 165
Laboratory, Cryogenic Engineering 165
Laboratory, Draper 89
Laboratory, Earth Resources 233
Laboratory, Energy 89
Laboratory, Fluid Mechanics 165
Laboratory for Biomechanics and Human Rehabilitation, Eric P. and Evelyn E. Newman 165
Laboratory for Computer Science 91
Laboratory for Electromagnetic and Electronic Systems 91
Laboratory for Information and Decision Systems 92
Laboratory for Manufacturing and Productivity 92
Laboratory for Medical Ultrasonics 165
Laboratory for Nuclear Science 92
Laboratory for Water Resources and Hydrodynamics, Ralph M. Parsons 145
Laboratory, George R. Harrison Spectroscopy 98
Laboratory, Heat Transfer 165
Laboratory, Intelligent Engineering Systems 144
Laboratory, Lincoln 93
Laboratory, Machine Dynamics 165
Laboratory, Man-Machine Systems 165
Laboratory, Mechanical Behavior of Materials 165
Laboratory, Media 105
Laboratory, Nuclear Reactor 96, 175
Laboratory of Architecture and Planning 93, 105
Laboratory of Electronics, Research 98
Laboratory, Reacting Gas Dynamics 165
Laboratory, REMERGENCE 144
Laboratory Requirement 47
Laboratory, Sloan Automotive 165
Laboratory, Structures 144
Laboratory, Surface 165
Laboratory, Vehicle Dynamics 165
Language and Mind 201
Language Proficiency 51, 61
Latin American Studies 184
Law-Related Studies 93
Leaders for Manufacturing Program 93, 161, 218
Lecture Series Committee 21
Lectures, Seminars, and Films 21
Letters of Recommendation 77
Libraries 13

Life Sciences, Bachelor of Science in 223
Light-Load Registration, Undergraduate 71
Lincoln Laboratory 93
Linear Accelerator Center, Bates 92
Linguistics and Philosophy, Department of 200
Linguistics and Philosophy, Subjects in 217D
Linguistics, Doctor of Philosophy in 203
List Visual Arts Center 22
Literature 193
Literature, Concentrations in 193
Literature Major 193
Literature, Minor Program in 193
Literature, Subjects in 181D
Loan Funds 67
Loan Plan, Parent 54, 65
Lowell Institute School 12

Machine Dynamics Laboratory 165
Magnet Laboratory, Bitter National 83
Major Course of Study 32
Management and Engineering, Master of Science in 161, 218
Management, Doctor of Philosophy in 218
Management fields of specialization 218
Management, Master of Science in 217
Management, Mineral Resources Engineering and 95, 161
Management of Technology, Master of Science in the 94, 129, 136, 146, 161, 169, 174, 180
Management, Programs for Executive Education in 219
Management Science, Bachelor of Science in 216
Management, Sloan School of 212
Management, Subjects in 127D
Man-Machine Systems Laboratory 165
Manufacturing and Materials Processing 164
Manufacturing and Productivity, Laboratory for 92
Map, Campus 14
Married Student Housing 25
Master in City Planning 59, 116
Master of Architecture 59, 110
Master of City Planning/Developing Areas Option 117
Master of Science in Aeronautics and Astronautics 129
Master of Science in Applied Biological Sciences 245
Master of Science in Architecture Studies 110
Master of Science in Ceramics 160
Master of Science in Chemical Engineering 135
Master of Science in Chemical Engineering Practice 135
Master of Science in Chemistry 228
Master of Science in Civil Engineering 143
Master of Science in Earth and Planetary Sciences, in Meteorology, or in Oceanography 232
Master of Science in Economics 189
Master of Science in Electrical Engineering and Computer Science 154
Master of Science in Health Sciences and Technology 254
Master of Science in Management 217
Master of Science in Management and Engineering 161, 218
Master of Science in Management of Technology 94, 129, 136, 146, 161, 169, 174, 180, 219
Master of Science in Materials Engineering 160
Master of Science in Materials Science 160
Master of Science in Mechanical Engineering 168
Master of Science in Metallurgy 160
Master of Science in Mineral Resources Engineering and Management 95
Master of Science in Nuclear Engineering 174
Master of Science in Ocean Systems Management 180
Master of Science in Operations Research 96
Master of Science in Physics 244
Master of Science in Political Science 206
Master of Science in Polymers 160
Master of Science in Real Estate Development 87
Master of Science in Technology and Policy 100, 129, 135, 146, 161, 174, 180
Master of Science in Transportation 88, 144, 180
Master of Science in Urban Studies and Planning 118
Master of Science in Visual Studies 110
Master of Science With and Without Specification 59
Master's and Bachelor's Degree Program, Combined 167
Master's and Bachelor's Degrees, Simultaneous Award of 60
Master's Degrees 59
Master's Degrees in City Planning and Architecture, Simultaneous 117
Master's Degrees in City Planning and Real Estate Development, Simultaneous 118
Master's Degrees in City Planning and Transportation, Simultaneous 117
Master's Degrees, Simultaneous Award of Two 59
Materials, Structures and 144
Materials, and Structures, Aeroelasticity, 128
Materials Engineer 136, 160
Materials Engineering, Master of Science in 160
Materials Engineering, Polymers and 135
Materials Processing Center 94
Materials Research in Archaeology and Ethnology, Center for 86
Materials Science 160
Materials Science and Engineering, Bachelor of Science in 157
Materials Science and Engineering, Center for 87
Materials Science and Engineering, Department of 155
Materials Science and Engineering, Doctor of Philosophy and Doctor of Science in 160
Materials Science and Engineering, Subjects in 26D
Materials Science, Master of Science in 160
Mathematics and Computer Science, Bachelor of Science in 238
Mathematics, Applied 235, 239
Mathematics, Bachelor of Science in 235
Mathematics, Department of 234
Mathematics, Doctor of Philosophy and Doctor of Science in 239
Mathematics, Pure 236, 239
Mathematics, Subjects in 167D
Mathematics, Theoretical 236
Mathematics with Computer Science, Bachelor of Science in 237
McGraw-Hill Observatory 82
Meal Plans 23
Mechanical Behavior of Materials Laboratory 165
Mechanical Engineer 169
Mechanical Engineering, Bachelor of Science in 165
Mechanical Engineering, Department of 162
Mechanical Engineering Design 164
Mechanical Engineering, Doctor of Philosophy and Doctor of Science in 169
Mechanical Engineering, Master of Science in 168
Mechanical Engineering, Research Laboratories and Programs in 165
Mechanical Engineering, Subjects in 15D
Mechanics and Materials 164
Mechanics and Physics of Fluids 127
Media Arts and Sciences 106
Media Laboratory 94, 105
Media Studies, Film and 184
Medical Physics, Doctoral Program in Medical Engineering and 254
Medical Services 26, 53, 64
Medical Ultrasonics, Laboratory for 165
Medieval Studies, Ancient and 184
Metallurgical Engineer 160
Metallurgy 160
Metallurgy, Master of Science in 160
Meteorology and Physical Oceanography, Center for 233
Meteorology, Oceanography, or Earth and Planetary Sciences, Master of Science in 232
Microbiology/Genetics 225
Middle East Program 94
Military Science, Subjects in 240D
Mineral Resources Engineering and Management 95, 161
Mineral Resources Research Institute, Mining and 95, 146
Mining and Mineral Resources Research Institute 95, 146
Minor in Humanities, Arts, and Social Sciences 33
Minor Program 61
Minor Program in Anthropology/Archaeology 190
Minor Program in Economics 187
Minor Program in History 192
Minor Program in Literature 193
Minor Program in Music 194
Minor Program in Philosophy 200
Minor Program in Political Science 205
Minor Program in Psychology 251
Minor Program in Science, Technology, and Society 209
Minor Program in Women's Studies 185
Minor Program in Writing 195
Minor Programs in Foreign Languages and Literatures 191
Miscellaneous Fees 54, 65
MIT Black Student Union 21
MIT Community Players 22
MIT Dance Workshop 21
MIT, History of 8
MIT-Japan Science and Technology Program 95
MIT Museum and Historical Collections 22
MIT Overview 8
MIT Press 13
MIT Program for Senior Executives 219
MIT Shakespeare Ensemble 22
MIT Student Blue Cross and Blue Shield Hospital Insurance 27
MIT Student House 24
Molecular Structure, Biophysical Chemistry and 225
Motor Vehicles 77
Museum, MIT Historical Collections and 22
Music 22, 194
Music, Minor Program in 194
Music, Subjects in 202D
Musical Theatre Guild 22

Nautical Collections, Hart 22
Naval Architecture and Marine Engineering, or Without Designation, Bachelor of Science in Ocean Engineering 177
Naval Construction and Engineering 180
Naval Engineer 180
Naval ROTC Program 38

Naval Science, Subjects in 242D
Neighborhood and Community Planning 114
Neurobiology 225
Newman Laboratory for Biomechanics and Human Rehabilitation, Eric P. and Evelyn E. 165
Nominations Committee 20
Non-Resident Doctoral Thesis Research Status 61
Nuclear and Particle Theory 244
Nuclear Engineer 174
Nuclear Engineering, Bachelor of Science in 172
Nuclear Engineering, Department of 170
Nuclear Engineering, Doctor of Philosophy and Doctor of Science in 174
Nuclear Engineering, Master of Science in 174
Nuclear Engineering, Subjects in 210D
Nuclear Reactor Laboratory 96, 175
Nuclear Science, Laboratory for 92
Nuclei and Particles, Division of 244
Nutrition Program, International Food and 90

Observatories and Facilities, Astronomy and Astrophysics 81
Observatory, Haystack Radio 82
Observatory, McGraw-Hill 82
Observatory, Wallace Geophysical 101
Ocean Engineer 180
Ocean Engineering and Oceanographic Engineering 255
Ocean Engineering, Department of 176
Ocean Engineering, Doctor of Philosophy and Doctor of Science in 179
Ocean Engineering Fields of Specialization 179
Ocean Engineering, Naval Architecture and Marine Engineering, or Without Designation, Master of Science in 177
Ocean Engineering, Subjects in 111D
Oceanographic Engineering and Oceanography 96
Oceanographic Engineering, Joint Program in Oceanography and, with Woods Hole Oceanographic Institution 61, 96, 136, 146, 154, 180, 225, 232, 255
Oceanography and Oceanographic Engineering 96
Oceanography, Center for Meteorology and Physical 233
Oceanography, Doctor of Philosophy and Doctor of Science 232
Oceanography, Meteorology, or Earth and Planetary Sciences, Master of Science in 232
Ocean Systems Management 180
Ocean Systems Management, Master of Science in 180
Off Campus Housing Service 24
Office of Career Services and Preprofessional Advising 27, 35
Office of Sponsored Programs 17, 63
Operations Research Center 96
Organization of the Graduate School 58
Organization of the Institute 17
Organizations and Research Facilities, Interdepartmental 80

Parent Loan Plan 54, 65
Parsons, Ralph M., Laboratory for Water Resources and Hydrodynamics 145
Pass/No Record Grading 32
Pass/Fail Option, Junior-Senior 34
Payment Plan, Bursary 54, 65
Payment of Tuition and Other Charges 54, 65
Personal Conferences 50, 51
Personal Files of Faculty and Staff 77
Philosophy, Bachelor of Science in 201
Philosophy, Doctor of Philosophy in 203
Philosophy, Minor Program in 200
Physical Education Requirement 47
Physical Oceanography 255
Physical Oceanography, Center for Meteorology and 233
Physics, Bachelor of Science in 242
Physics, Department of 240
Physics, Doctor of Philosophy and Doctor of Science in 244
Physics, Master of Science in 244
Physics Requirement 41
Physics, Subjects in 71D
Physics with Electrical Engineering 243
Planning and Architecture, Laboratory of 93, 105
Planning and Policy, Environmental 117
Planning, Bachelor of Science in 113
Planning, Master of Science in Urban Studies and 118
Planning, Transportation 117
Plasma Fusion Center 97
Policies and Procedures, Institute Regulations 74
Policy and Planning, Environmental 117
Policy, Industrial Development, and Technology, Center for 87
Policy Statement on the Use of Alcohol 75
Political Science, Accelerated Master of Science in 206
Political Science, Bachelor of Science in 205
Political Science, Department of 204
Political Science, Doctor of Philosophy in 206
Political Science, Master of Science in 206
Political Science, Minor Program in 205
Political Science, Subjects in 155D
Polymers 160
Polymers and Materials Engineering 135
Polymers Laboratories, Fibers and 165
Polymers, Master of Science in 160
Polymer Science and Technology, Program in 97
Power Engineering 97
Prelaw Education 35
Premedical Education 35
Preprofessional Advising, Office of Career Services and 27, 35
Privacy, Committee on 77
Privacy of Student Records 76
Procedure for Retention of Student Status at MIT 70
Process and Systems Engineering 134
Processing Charges for Late Changes in Registration 54, 65
Program, Academic 9, 30
Program for Senior Executives, MIT 219
Program for Two Bachelor's Degrees 34
Program in Applied Biological Sciences 245
Program in Polymer Science and Technology 97
Program in Science, Technology, and Society 45 98, 208
Programs, Cooperative 53, 64
Programs, Cooperative, with other Institutions 38, 61
Programs, Departmental 9, 30, 103
Programs for Double Competence in Humanities/ Social Science and Science/ Engineering 98
Programs for Executive Education in Management 219
Project Athena 13
Project Interphase 50
Propulsion and Energy conversion 128
Propulsion Laboratory, Combustion and 165
Psychology 184, 257, 83D
Psychology, Minor Program in 251
Public Policy, Urban Management, and the Law 114
Publications, Student 21
Pure Mathematics 236, 239

Racist Behavior, Institute Policy on 74
Radiological Science, Doctoral Program in 248
Reacting Gas Dynamics Laboratory 165
Reaction Engineering 134
Reactor Laboratory, Nuclear 96, 175
Real Estate Development, Center for 87, 105
Real Estate Development 116
Real Estate Development, Master of Science in 87
Real Estate Development, Simultaneous Master's Degrees in City Planning and 118
Recommendation, Letters of 77
Records, Privacy of Student 76
Registration Procedures 70
Registration, Charges for Late Changes in 54, 65
Registration, Undergraduate, Light-Load 71
Regular Graduate Admissions 62
Regulations, Academic Procedures and Institute 70
Regulations, End-of-Term 73
Regulations, Institute 74
Religious Beliefs, Institute Policy on Student Absence Due to 74
Religious Organizations 21
REMERGENCE Laboratory 144
Requirement, Calculus 41
Requirement, Chemistry 40
Requirement in the Humanities, Arts, and Social Sciences 42
Requirement, Laboratory 47
Requirement, Physical Education 47
Requirement, Physics 41
Requirement, Science 40
Requirement, Science Distribution 46
Requirement, Writing 41
Requirements for Advanced Degrees, Undergraduate 62
Requirements for Graduate Degrees, General 59
Requirements, General Institute 40
Requirements, Residence 59
Research and Teaching Assistantships 67
Research Facilities, Interdepartmental Organizations and 80
Research Institute, Mining and Mineral Resources 95, 146
Research Laboratory of Electronics 98
Research Room, Women's Studies 35, 101
Research Staff Members, Graduate Student Status for 63
Residence/Orientation Week 24
Residence Requirements 59
Resources, Educational 12
Resources Research Institute, Mining and Mineral 95, 146
Retention of Student Status at MIT, Procedure for 70
Review of Student Records 76
Room and Board 24, 53, 64
ROTC Programs 36
Russian. See Subjects in Foreign Languages and Literatures
Russian Studies 185

S.B. - M.C.P. Option, Five-Year 115
School of Architecture and Planning 104
School of Chemical Engineering Practice 135
School of Engineering 119
School of Humanities and Social Science 182
School of Management, Sloan 212

School of Science 220
School-Wide Electives in Engineering 121, 235D
Science and Technology Program, MIT-Japan 95
Science Distribution Requirement 46
Science/Engineering, Programs for Double Competence in Humanities/Social Science and 98
Science Requirement 40
Science, School of 220
Science, School of, Interdepartmental Laboratories in the 221
Science, Technology, and Society, Minor Program in 209
Science, Technology, and Society, Program in 45, 98, 208
Science, Technology, and Society, Subjects in 230D
Sciences, Biomedical 82, 254
Sea Grant College Program 98
Second S.B. Degree in Mechanical Engineering 167
Secondary School Preparation 50
Selection of Major Course of Study 32
Seminars, Lectures, and Films 21
Seminars, Undergraduate Seminars and Freshman Advisor 34
Senior Executives, MIT Program for 219
Services, Student 26
Settlement Design, Housing and 110
Shakespeare Ensemble, MIT 22
Simultaneous Award of Bachelor's and Master's Degrees 60
Simultaneous Master's Degrees in City Planning and Architecture 117
Simultaneous Master's Degrees in City Planning and Real Estate Development 118
Simultaneous Master's Degrees in City Planning and Transportation 117
Simultaneous Registration for Two Master's Degrees 59
Single Student Housing, Graduate 25
Single Student Housing, Undergraduate 23
Sloan Automotive Laboratory 165
Sloan Fellows Program, Alfred P. 219
Sloan School of Management, Alfred P. 212
Social Committee 20
Social Science, School of Humanities and 182
Social Sciences, Humanities, and Arts Requirement 42
Solid-state, Laser, Plasma, and Atomic Physics 244
Sororities, and Independent Living Groups, Fraternities, 24
Space Research, Center for 87
Spanish. See Subjects in Foreign Languages and Literatures
Special Graduate Students 63
Special and Interdisciplinary Programs in Humanities and Social Sciences 183
Special Interest Groups 21
Special Loan Funds, Graduate 67
Special Program for Urban and Regional Studies 118
Special Programs, Subjects in 228D
Special Student Admissions 53, 63
Spectroscopy Laboratory 98
Sports. See Athletics
Statement of Disciplinary Committee Procedures 75
Statistics Center 99
Structures Laboratory 144
Structures and Materials 144
Structures, Materials, and Aeroelasticity 128
Student Absence Due to Religious Beliefs, Institute Policy on 74
Student Activities, Association of 20
Student Center Committee 20
Student Committee on Educational Policy 20
Student Directory, Privacy of Information 77
Student Employment 54, 63, 67
Student Government, Graduate 20
Student Government, Undergraduate 20
Student Health Program 26
Student House, MIT 24
Student Information Processing Board 20
Student Publications 21
Student Records, Privacy of 76
Student Records, Review of 76
Student Services 26
Student Status at MIT, Procedure for Retention of 70
Study at Other Universities 38, 61
Subject Credits and Designations 70
Subjects, Distribution 43
Subjects, Elective 45
Subjects in Aeronautics and Astronautics 145D
Subjects in Aerospace Studies 238D
Subjects in Anthropology/Archaeology 199D
Subjects in Applied Biological Sciences 179D
Subjects in Architecture 34D
Subjects in Biology 67D
Subjects in Brain and Cognitive Sciences 79D
Subjects in Chemical Engineering 84D
Subjects in Chemistry 48D
Subjects in Civil Engineering 2D
Subjects in Earth, Atmospheric, and Planetary Sciences 101D
Subjects in Economics 119D
Subjects in Electrical Engineering and Computer Science 51D
Subjects in Engineering School-Wide Electives 235D
Subjects in Foreign Languages and Literatures 185D
Subjects in Health Sciences and Technology 223D
Subjects in History 193D
Subjects in Humanities 181D
Subjects in Linguistics and Philosophy 217D
Subjects in Literature 181D
Subjects in Management 127D
Subjects in Materials Science and Engineering 26D
Subjects in Mathematics 167D
Subjects in Mechanical Engineering 15D
Subjects in Military Science 240D
Subjects in Music 202D
Subjects in Naval Science 242D
Subjects in Nuclear Engineering 210D
Subjects in Ocean Engineering 111D
Subjects in Physics 71D
Subjects in Political Science 155D
Subjects in Science, Technology, and Society 230D
Subjects in Special Programs 228D
Subjects in Technology and Policy 237D
Subjects in Theatre and Dance 205D
Subjects in The Writing Program 206D
Subjects in Urban Studies and Planning 92D
Surface Laboratory 165
Synthetic Fuels Center 90
Systems and Computation, Engineering 140
Systems and Control Science 92
Systems, Computers, and Control 164
Systems Engineering 125
Systems Research, Center for Information 85
Talbot House 22
Tang Residence Hall, Ping Yuan 25
Teaching and Research Assistantships 67
Technology, Accreditation Board for Engineering and 120, 125, 132, 139, 140, 150, 157, 165, 167, 177, 178
Technology and Development Program 99
Technology and Policy 100
Technology and Policy, Master of Science in 100, 129, 135, 146, 161, 174, 180
Technology, and Society, Program in Science, 43, 98, 208
Technology and Policy, Subjects in 237D
Technology Children's Center 27
Technology Community Association 21
Technology Community Women 21
Technology, Health Sciences and 90
Technology, Policy, and Industrial Development, Center for 87
Technology Progam, MIT-Japan Science and 95
Technology Review 17
Test of English as a Foreign Language (TOEFL) 51, 63
Theatre 22
Theatre and Dance, Subjects in 205D
Theoretical Mathematics 236
Theoretical Physics, Center for 244
Thesis 59, 60
Toroidal Confinement Experiments 97
Tours of the Institute 15
Toxicology, Doctoral Program 248
Traineeships, Fellowships, and Scholarships 66
Transcripts and Grade Reports 71
Transfer Admissions, College 52
Transportation 164
Transportation, Master of Science in 88, 144, 180
Transportation Planning 117
Transportation, Simultaneous Master's Degrees in City Planning and 117
Transportation Studies, Center for 88, 144
Transportation Systems Division 144
Tufts University 61
Tuition and Fees 53, 64
Tuition and Other Charges, Payment of 54, 65
Two Bachelor's Degrees, Program for 34
Two Master's Degrees, Simultaneous Registration for 59
Undergraduate Academic Standards 71
Undergraduate Admissions, Foreign. See International Undergraduate Admissions
Undergraduate Association 20
Undergraduate Education at MIT 29
Undergraduate Education, Dean for 17
Undergraduate Interdepartmental Opportunities 80
Undergraduate Projects Laboratory 125
Undergraduate Requirements for Advanced Degrees 62
Undergraduate Research Opportunities Program (UROP) 34, 100
Undergraduate Seminars and Freshmen Advisor Seminars 34, 101
Undergraduate Single Student Housing 23
Undergraduate Student Government 20
Undergraduate Students, Costs for 53
Unified Engineering 124
Unspecified Degree Programs for Interdisciplinary Study 101
Urban and Regional Planning in Developing Countries 115
Urban Management, and the Law, Public Policy 114

Urban Studies and Planning, Department of 112
Urban Studies and Planning, Doctor of Philosophy in 118
Urban Studies and Planning, Master of Science in 118
Urban Studies and Planning, Subjects in 92D
Urban Studies, Bachelor of Science in. See Planning, Bachelor of Science in
Urban Studies, Fieldwork and Internships in 117
UROP (Undergraduate Research Opportunities Program) 34, 100

Vehicle Dynamics Laboratory 165
Vibrations Laboratory, Acoustics and 165
Visiting Committees 17
Visual Arts Center, Albert and Vera List 22
Visual Arts, Committee on the 22
Visual Studies, Master of Science in 110

Wallace Astrophysical Observatory 81
Wallace Geophysical Observatory 101
Water Resources and Environmental Engineering Division 145
Water Resources and Hydrodynamics, Ralph M. Parsons Laboratory for 145
Water Resources Systems, Hydrology and 145
Wellesley-MIT Exchange Program 38, 61
Westgate 25
Whitaker College of Health Sciences, Technology, and Management 247
Whitehead Institute for Biomedical Research 101
Women's Independent Living Group 24
Women's Studies, Minor Program in 185
Women's Studies Program 35, 101, 185
Women's Studies Research Room 35, 101
Woods Hole Oceanographic Institution 61, 96, 255
Woods Hole Oceanographic Institution, Joint Program in Oceanography and Oceanographic Engineering with 61, 96, 136, 146, 154, 180, 225, 232, 255
Work-Study, College 55
Writing Center 195
Writing, Minor Program 195
Writing Program 194
Writing Program, Subjects in The 206D
Writing Requirement 41

Colophon

Typeset in Helvetica by Modern Graphics, Inc., Weymouth, Massachusetts. Type for Chapters V and VI prepared in house at MIT using *Interleaf Publishing Software.*

Film for cover photographs prepared by Collier/Wright, Cambridge, Massachusetts.

Printed and bound by Bawden Printing, Inc., Eldridge, Iowa, on 33 pound white mando publication offset.

Front and back cover photograph by Bradford Herzog.

President's Statement Page 4 (clockwise from left): Peter Mui, Trina Arnett, Bradford Herzog, Bradford Herzog; page 5: Jim Harrison.

Chapter I Page 6: Trina Arnett; page 7 (from left to right): Trina Arnett, Trina Arnett, Trina Arnett; page 8: MIT Museum and Historical Collections; page 9: Bradford Herzog; page 10: Linda Cuccurullo; page 12: Randall Warniers; page 13: Bradford Herzog; page 16 (from left to right): Randall Warniers, Gordon R. Haff, Tim Vasicek; page 17: Trina Arnett.

Chapter II Page 18: Trina Arnett; page 19 (clockwise from upper left): Nancy Ferrari, Trina Arnett, Norman Chen, Virginia Such, Trina Arnett; page 20: Alys Longworth; page 21: Bradford Herzog; page 23: Trina Arnett; page 24: Randall Warniers; page 25: Chris Maynard; page 26: Trina Arnett.

Chapter III Page 28: Trina Arnett; page 29 (clockwise from upper left): Nancy Ferrari, Jean Vivant, Randall Warniers, Bradford Herzog; page 30: Randall Warniers; page 33: Bradford Herzog; page 34: Margo Woodruff; page 37: Alys Longworth; page 41: Jim Snyder; page 46: Randall Warniers; page 47: Bradford Herzog; page 48: Bradford Herzog; page 49: Trina Arnett; page 51: Bradford Herzog; page 53: Winston I. Smith; page 55: Bradford Herzog.

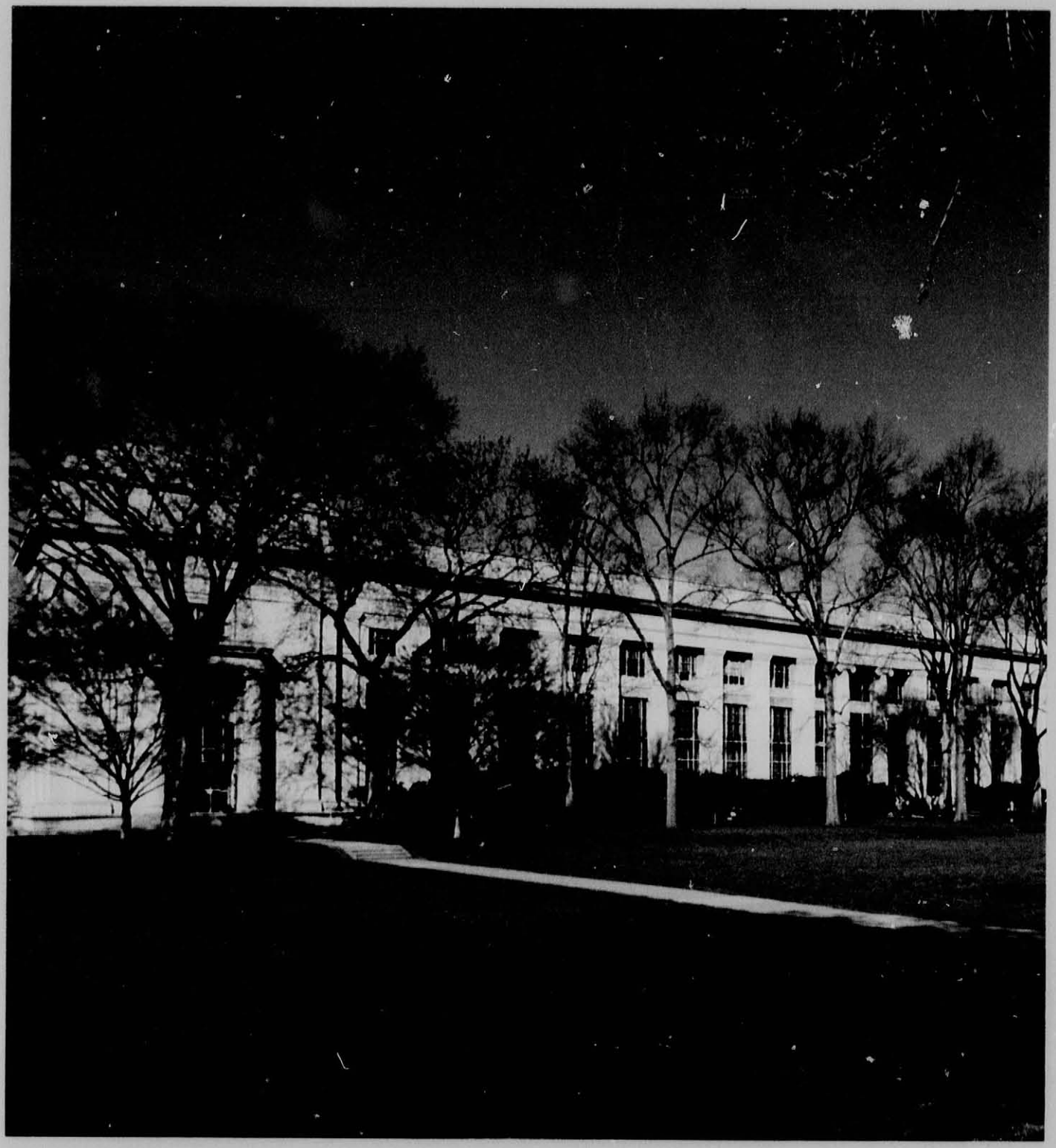
Chapter IV Page 56: Bradford Herzog; page 57 (clockwise from upper left): Christopher Brown, Jim Harrison, Mark Wilson, David Ludlow, Mark Wilson; page 58: Bradford Herzog; page 60: Bradford Herzog; page 61: Susan Lapides; page 62: Christopher Brown; page 63: Christopher Brown; page 65: Bradford Herzog; page 66 (left to right): Bradford Herzog, Bradford Herzog.

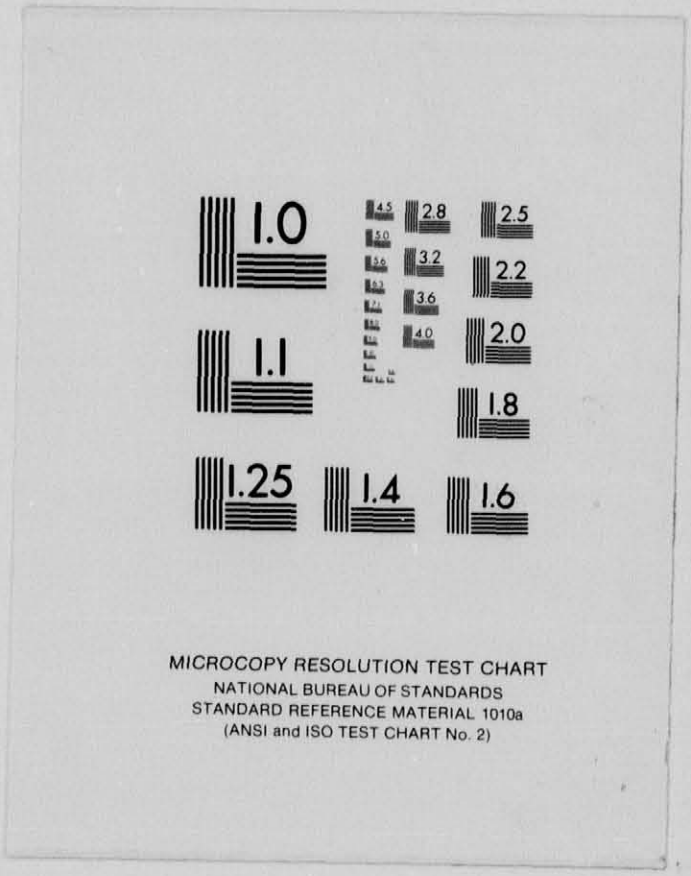
Chapter V Page 68: Bradford Herzog; page 69 (clockwise from upper left): Mark Wilson, Laurie Goldman, Bradford Herzog.

Chapter VI Page 78: Bradford Herzog; page 79 (clockwise from upper left): Bradford Herzog, Randall Warniers, Donna Coveney.

Chapter VII Page 102: Trina Arnett; page 103 (clockwise from upper left): Ariel Poler, Laurie Sokolsky, Bradford Herzog, Trina Arnett, Mark Wilson; page 104 (top to bottom): Susan Lapides, Susan Lapides; page 119: Donna Coveney; page 182: Donna Coveney; page 212: Bradford Herzog; page 220: Bradford Herzog; page 247 (top to bottom): Bradford Herzog, Bradford Herzog.

Chapter VIII Page 256: Bradford Herzog; page 257 (clockwise from upper left): Bradford Herzog, Randall Warniers, Bradford Herzog, Donna Coveney.





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

24 : 1