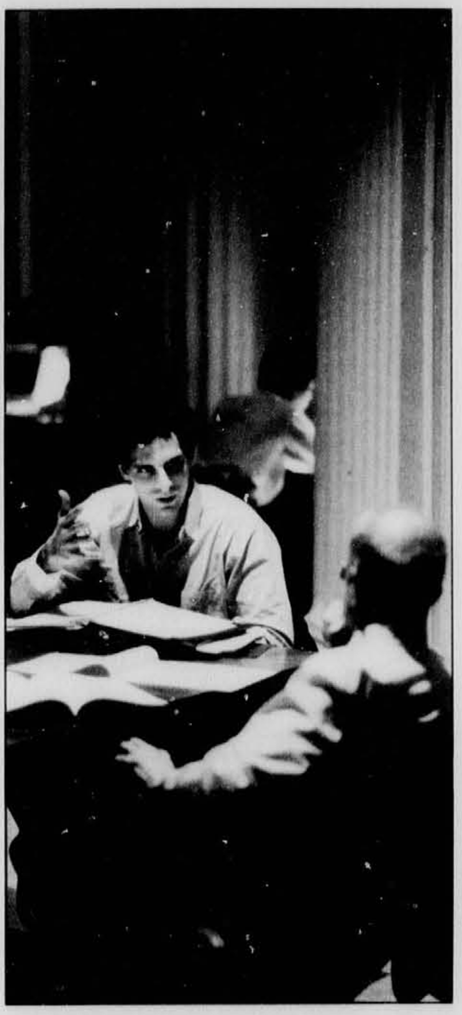
M.I.T. ANNUAL CATALOGUES AND BULLETINS
1986-87

Bulletin 1986-87

Massachusetts Institute of Technology

Courses and Degree Programs Issue
1986-87



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August 1986

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 Undergraduate Seminar Program, the IAP Guide, the Summer Session Catalogue, and the Fall Undergraduate Seminar Program.

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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, 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.

Contents

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 That early, and somewhat naive, optimism has been replaced by a skepticism and by an alarming decline in scientific literacy in this country.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.

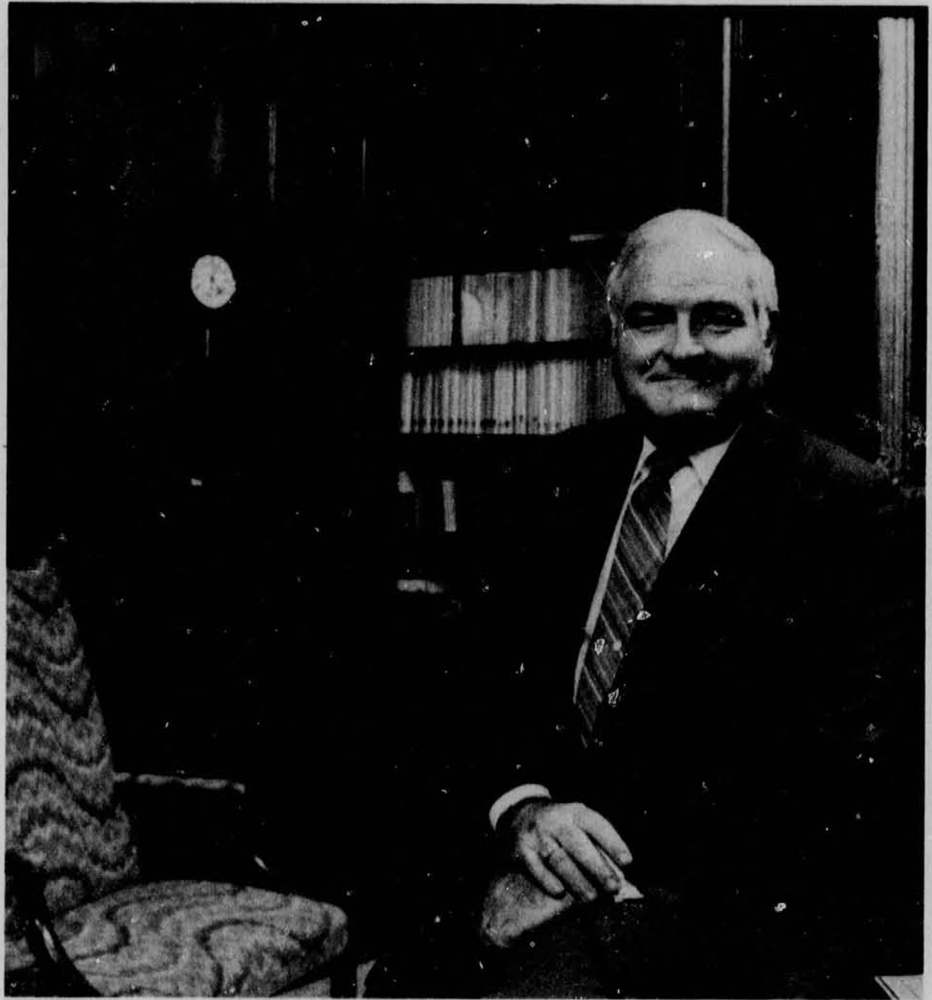
Scientific inquiry is, at once, a most natural and highly refined expression of the human mind and spirit. It is derived from native curiosity about the nature of our world and about the universe, and it results in speculations and concepts which help to give meaning and order to that world. Engineering 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.

From the Inaugural Address of
Paul E. Gray
President



I This is MIT

This is MIT

An Overview

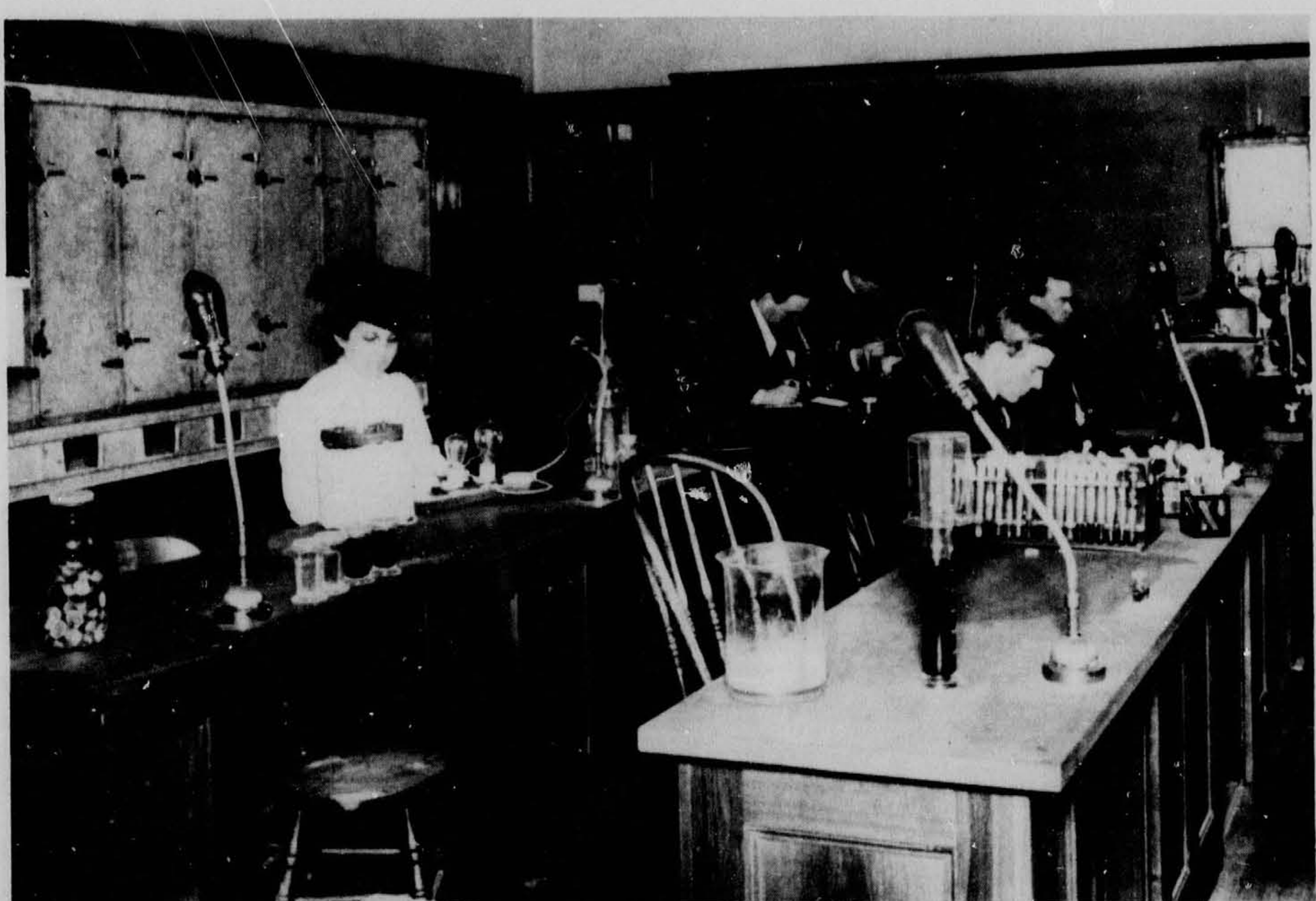
On February 20, 1865, four years after approval of its founding charter, the Massachusetts Institute of Technology opened its doors to admit the first class of 15 students. The event marked the culmination of an effort by William Barton Rogers, MIT's founder and first president, to create a new kind 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 22 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 1985-86, MIT students came from all 50 states and the District of Columbia, Puerto Rico, the Virgin Islands, Guam, and 97 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 intermixing of ages, disciplines, and nationalities, which is 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 22 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 listed 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
Linguistics and Philosophy
Political Science

Sloan School of Management
Management

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

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, environmental studies, 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 which 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 I and Course I-A are curricula in Civil Engineering; the number 1.05 indicates a subject given in Civil Engineering. The Department of Civil Engineering as a whole can also be referred to as Course 1 or Course I.

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.

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August

8	Last day to petition for September Advanced Standing Exam and to return application card for Postponed Finals
11	Payment for first term due
27	Transfer Student Orientation Week begins
29	Freshman Orientation Week begins

September

1	Labor Day *(Holiday)*
2	Graduate Student Orientation Week begins
2-3	Advanced Standing Exams and Postponed Finals
2-4	International Open House
8	Registration Day
9	First day of classes
26	Application for advanced degrees in February due in Registrar's Office, E19-335. $20 fee after this date.

October

10	Add Date. Last day to add subjects to registration. $20 processing charge for any add allowed after this date. Last day for juniors and seniors to change an elective to or from P/F grading.
13-14	Columbus Day Vacation
15	Automatic withdrawal date for students not having completed six steps of registration
17	Deadline for students to turn in Freshman Evaluation Forms
22	Deadline for instructors to turn in Freshman Evaluation Forms

November

11	Veterans Day *(Holiday)*
21	Last day to petition for December Advanced Standing Exam
21	Drop Date. Last day to cancel subjects from registration. **Undergraduates** must petition to Committee on Academic Performance; **graduates** must petition to Committee on Graduate School Policy for a cancellation after this date. $20 processing charge for any drop allowed after this date.
27-28	Thanksgiving Vacation

December

1-2	Second-term registration material available in Building 10 Lobby
5	Last day for changing thesis title. $20 fee after this date.
11	Last day of classes
12	Deadline for students to turn in Freshman Evaluation Forms
16-19	Final exam period
19	Registration material for second term due in Registrar's Office, E19-335. $20 fine for registration received after this date.
20	Christmas Vacation begins (through January 4)
30	Deadline for instructors to turn in Freshman Evaluation Forms

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January

4 Last day of Christmas Vacation

5 First-term grade reports mailed

5 First day of Independent Activities Period

9 Doctoral theses due for January

12 Payment for second term due

16 Theses, other than doctoral, due for January

16 Last day to go on or off February degree list

16 Last day to petition for February Advanced Standing Exam and to return application card for Postponed Finals

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

28 Last day of Independent Activities Period

29 Vacation begins (through February 1)

February

1 Last day of vacation

2 Registration Day

3 First day of classes

5 Grade reports for January period mailed

7 Advanced Standing Exams and Postponed Finals

16-17 Washington's Birthday Vacation

20 Application for advanced degrees in June due in Registrar's Office, E19-335. $20 fee after this date.

March

6 Add Date. Last day to add subjects to registration. $20 processing charge for any add allowed after this date. Last day for juniors and seniors to change an elective to or from P/F grading.

9 Automatic withdrawal date for students not having completed six steps of registration

20 Deadline for students to turn in Freshman Evaluation Forms

23-27 Spring Vacation

30 Deadline for instructors to turn in Freshman Evaluation Forms

April

10 Last day for changing doctoral thesis title. $20 fee after this date.

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

20-21 Patriots' Day Vacation

24 Drop Date. Last day to cancel subjects from registration. **Undergraduates** must petition to Committee on Academic Performance; **graduates** must petition to Committee on Graduate School Policy for a cancellation after this date. $20 processing charge for any drop allowed after this date.

24 Last day to petition for May Advanced Standing Exam

May

1 Doctoral theses due for second term

1 Summer session registration material due in Registrar's Office, E19-335

4-5 First-term registration material available in Building 10 Lobby. Reference copies of new subject descriptions available in departmental headquarters, libraries, and the Information Center.

8 Theses, other than doctoral, due for second term

14 Last day of classes

15 Last day to go on or off degree list

18-20 Final exam period

21 Registration material for continuing students due in Registrar's Office, E19-335. $20 fine for any registration received from continuing students after this date.

25 Memorial Day *(Holiday)*

June

1 Commencement exercises

1 Second-term grade reports mailed to home address

8 Summer Session begins (through August 19)

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 on ongoing projects.

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.

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 a 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 Library; 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-216, for a library privilege card.

Project Athena

Project Athena is a major Institute-wide experiment to integrate modern 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 1985-86 approximately 110 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 11 public clusters on the MIT campus. The network, when complete, will contain approximately 1,500 work stations located in academic facilities, laboratories, libraries, and living groups.

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 which 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 E19-738, MIT, Cambridge, Massachusetts 02139.

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 multi-user 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 between users and the distribution of computing resources.

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.

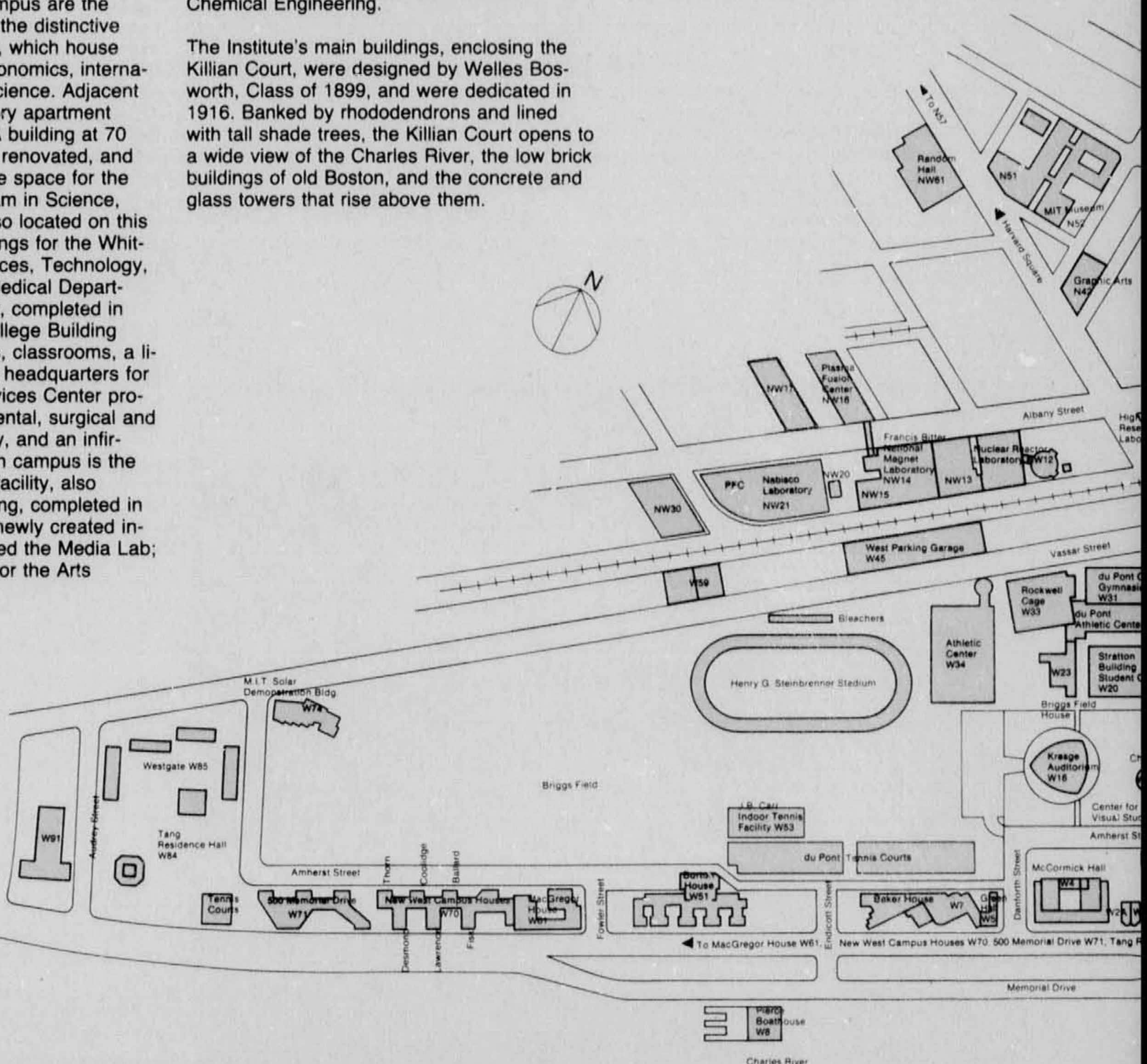
The Campus

MIT's 142-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 and the Program in Science, Technology, and Society. 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 Lab; 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 Sloan Laboratory, the Guggenheim Laboratory, and the Center for Advanced Engineering Study.



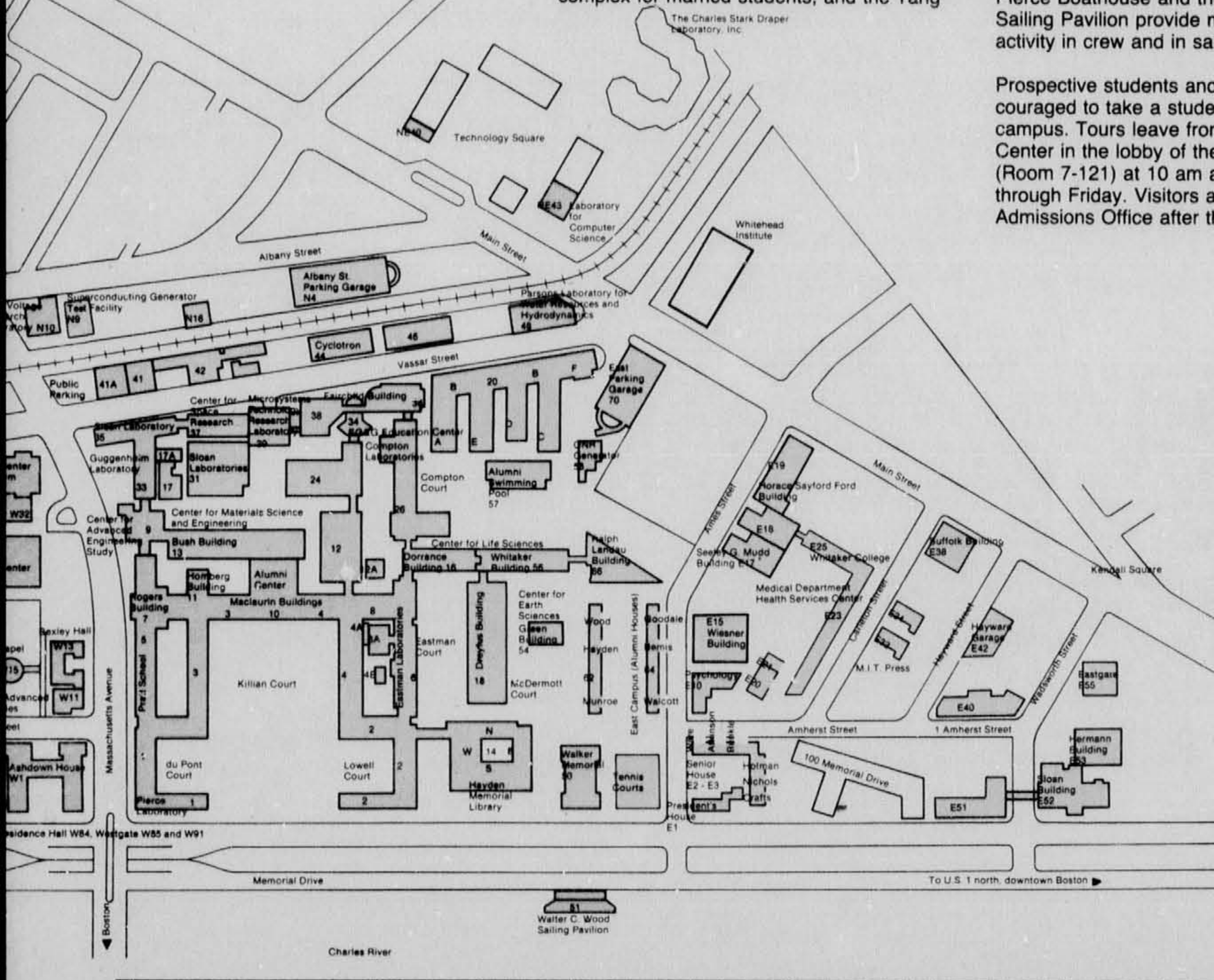
Across Massachusetts Avenue, on West Campus, is the Student Center (the Julius Adams Stratton building), which contains social rooms, cafeterias, offices for student activities, music rooms, a spacious library, and recreational and commercial facilities. The Student Center Plaza is bounded on the west 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 westernmost 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 Athletics Center includes an 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 Office after the tour (Room 3-108).



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 historical places of 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 90 distinguished leaders of science, engineering, industry, and education, and (ex officio) the President and the Treasurer 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 22 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 Chairman, the Associate Chairman, 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 chairman 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 Chairman 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 80,000 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 70 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.

II Campus Life

Campus Activities

There is much more to an MIT education than study and research in classrooms and laboratories. Many 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 and occasionally publishes a course evaluation guide. 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 all 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 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 is composed of elected representatives of all Courses, Ashdown House, Tang Hall, Green Hall, Eastgate, Westgate, and international students. The organization 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 nominates two students to serve on the faculty Committee on Graduate School Policy 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.*

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 may be continued following graduation.

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, 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 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 and nine softball diamonds (two with lights). 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 14 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; *Ergo; Technique,* the senior yearbook; *Rune,* an annual literary magazine; *How to Get Around MIT (HowToGAMIT),* the MIT community guide; 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 80 non-athletic activities and clubs at MIT (many of them open to both faculty and students), including the Outing Club, the White Water Club (canoe and kayak), 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 21 international student clubs 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 MIT 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, and strategic games.

Technology Community Association (TCA)

Managed by undergraduates, TCA conducts a diversified program of year-round services to the MIT community, including a book exchange, duplicating machines and silkscreening facilities for student use, and an annual blood donor drive. 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 including Tech Show, an original student-written musical which is usually produced in the spring term. MIT students are given first priority in filling all manager, director, designer, orchestra, cast, and technical positions.

The MIT Community Players is composed of 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, and photography is displayed 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 this past year included Berenice Abbott: Vision of the 20th Century — five decades of photographs by the renowned American photographer; and Piece by Piece — architectural drawings and models by Italian architect Renzo Piano.

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. The opening of a new undergraduate residence in 1981 now allows for the housing of some transfer and readmitted students.

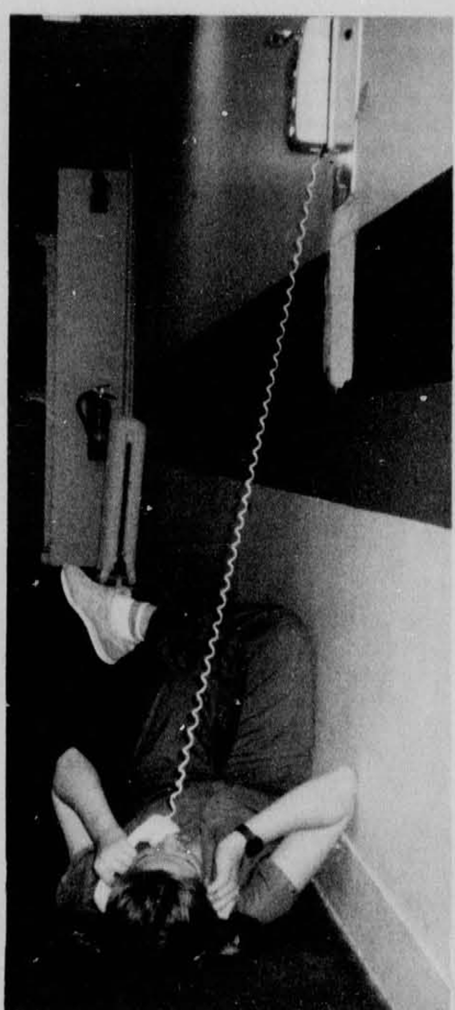
The central purpose of the residential system is to provide an environment conducive to personal development as well as academic achievement. The Institute relies greatly on the initiative and responsibility of both individual students and student government organizations in the residences.

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) and MacGregor House (all male), the Institute Houses have coeducational living facilities. However, most of the coed Houses also have "single-sex" living areas within the House. While we are unable to guarantee the assignment of a freshman to any particular House, an effort is made to assign students to one of their top choices. It is also usually possible to transfer from one House to another after the first term.

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 1986-87, the average rents for the Houses range from $965 to $1,276 per term.

A student cancelling a room assignment after the stated deadline of July 11 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 1986-87

The meal plans for all MIT students, graduate and undergraduate, combine the use of points for commons meals and cash for a la carte meals and snacks. This unique plan, with the help of a transaction processor called the Vali-Dine System, provides the students with a wide range of options, flexibility, and financial equity.

All students living in Houses which have dining rooms (Baker House, MacGregor House, McCormick Hall, and 500 Memorial Drive) are required to take the following meal plan: freshmen "360" plan, sophomores "310" plan, juniors "260" plan, and seniors "210" plan.

The meal plans as listed are basically the same and can be used in the "commons" dining room at Baker House or at a la carte prices at Lobdell and 20 Chimneys in the Student Center, Morss Hall and Pritchett in Walker Memorial, the snack bar and dining room at 500 Memorial Drive, and the dining rooms in McCormick and MacGregor halls. There will be a full refund of the unused balance on any meal plan to those students who cancel their plan or withdraw from the Institute. The only exception will be for those students who are required to be on a meal plan and do not use their minimum requirement.

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.

Plan Prices per Term

560 Plan	$987
460 Plan	842
410 Plan	769
360 Plan	697
310 Plan	624
260 Plan	551
210 Plan	478
160 Plan	406
$200.00 Plan	200

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, Room E18-301, MIT. 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 E18-301, 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 7-133, MIT, 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 391 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 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 $2,158 to $2,530 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 athletic, Student Center, and main campus buildings.

Rooms are furnished with a bed, desk, chair, lamp, and dresser, and range from $2,138 to $2,378 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 $232 to $276 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 $425 to $647 per month and include all utilities except telephone.

Married student housing is managed by the MIT Housing Office, Room E18-301, 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 which 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 of hospital and accident insurance in which all regular students are enrolled unless they submit a written request to waive coverage.

All regular and special students are entitled to comprehensive health care services given by the Medical Department at the Health Services Center (Building E23) generally without further charge. As exceptions to this, charges are made for completion of pre-entry medical forms, administration of required pre-entry 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. Student spouses may use the Department on a fee-for-service basis or receive the same benefits as a student by paying the $360 Health Service fee for coverage from September 1, 1986 through August 31, 1987.

The MIT Medical Department is a multispecialty group practice which employs 23 full-time and 40 part-time physicians as well as other professional support personnel. The Department's medical staff provides primary care in the areas of internal medicine, surgery, and pediatrics. Specialists are also available in gynecology, orthopedics, ophthalmology, urology, allergy, neurology, nutrition, endocrinology, dermatology, otolaryngology, gastroenterology, pathology, podiatry, radiology, psychiatry, and social work services. The Department provides a pharmacy and a full-time optometry service including contact lens services. Laboratory, X-ray, and other diagnostic testing facilities are also available, as is a health education and patient advocacy service. A major goal of the Department is to provide high-quality, accessible medical care; students are encouraged to identify a primary physician who coordinates their health care.

A dental service, which offers dental treatment for students and their spouses, is available on a fee-for-service basis, as is a pediatric service.

Initial consultations with a member of the psychiatric service are available to all students and their spouses without charge. Prolonged psychiatric treatment cannot be provided by the Institute psychiatric staff; students requiring such treatment will be referred to private psychiatrists or psychiatric clinics in the area.

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 Student Health Programs. 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. Students are also required to be immune to measles and rubella (German measles) prior to arrival 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 it completed by the Medical Department. There will be a charge for this service and for any required immunizations.

An 18-bed Inpatient Service is operated by the Medical Department for students and spouses with acute illness or contagious diseases who cannot be cared for in their dormitories or other living groups but for whom hospitalization in a general hospital is inappropriate. Children are not admitted to the Inpatient Service, but if necessary, are referred to a nearby hospital offering pediatric care. Patients requiring major surgery or treatment for serious illness are sent to one of the Boston or Cambridge hospitals where their care is usually supervised by one of the Medical Department physicians or surgeons.

All 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 MIT Off-Hours Service. Advice may be obtained day or night by calling 253-1311. 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.

Except under unusual circumstances and with the approval of the Medical Director, health care services covered by the MIT Medical Department do not include the cost of medical care given off campus or hospitalization except in the MIT Inpatient Service. The cost of hospitalization and outside medical care for serious illness or injury is extremely high; in Boston-area hospitals it exceeds $600 per day. For this reason, it is extremely important that students maintain adequate health insurance for themselves and family members. All regular students will be enrolled automatically in the MIT hospital insurance program and billed for each semester. US citizens covered under their own or their family's policy must request waiver of the MIT coverage by completing the form enclosed with the Financial Registration material. New waiver request forms must be filed each academic year. All non-US citizens must demonstrate that they have coverage equivalent to the MIT insurance by submitting a copy of their insurance policy to the MIT Medical Department Student Insurance Office together with the completed waiver request.

Special students taking two or more courses are eligible to purchase the MIT hospital and accident insurance, but are not enrolled automatically.

Annual Rates (September 1, 1986-August 31, 1987)

	MIT Medical Department	Hospital & Accident Insurance
Student	included in tuition	$276
Spouse	$360 or fee for service	$864
Child(ren)	fee for service	$276

Office of Career Services and Preprofessional Advising

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 are 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.

More than 400 companies, government agencies, and graduate schools make recruiting visits to the Office each year. These visits are publicized in descriptive notices which 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 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.

Any individual with career interests, questions, or concerns should call (617) 253-4733 (or 4737) 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 which can accommodate children from infancy to age five. All of the programs reflect the great diversity of cultures that one finds at the Institute.

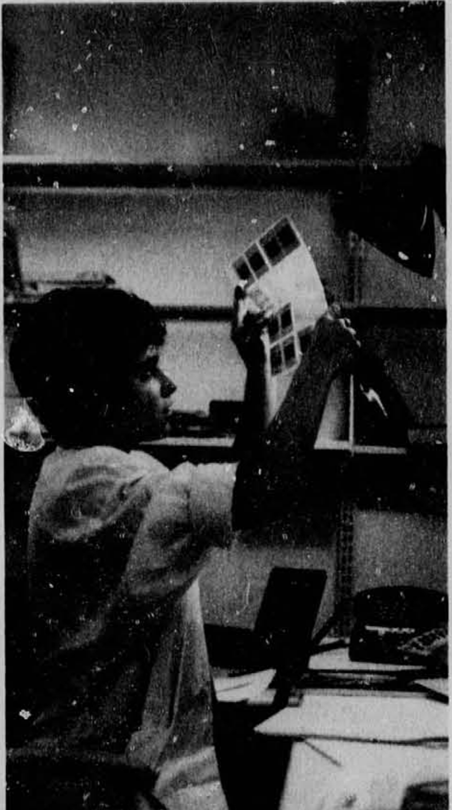
Family Day Care is organized by the Child Care Office and is an arrangement in the home of a day care provider who has been licensed by the Commonwealth of Massachusetts. Each family day care home operates independently offering its own attitudes and activities. The Child Care Office puts providers and users in touch with each other. Actual arrangements are made by the families involved. Fees range from $3.00 to $3.50 per hour. Family day care homes are located in Eastgate and Westgate, as well as in other parts of Cambridge and surrounding communities.

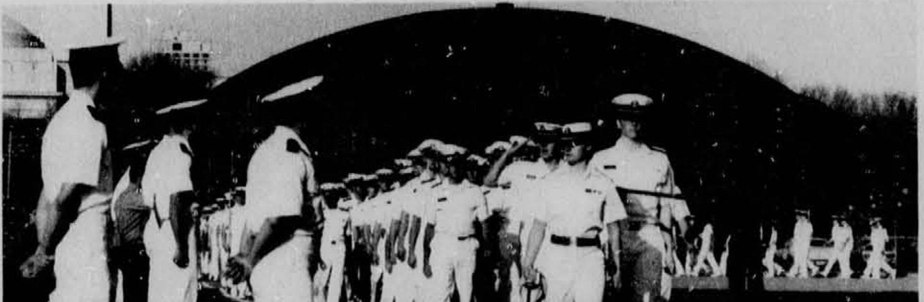
Technology Children's Center, Inc. (TCC) is a private, nonprofit corporation which operates two programs on campus for children who are at least two years and nine months old:

The Half-Day Program 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, with classrooms located in Eastgate and in Westgate. Weekly fees for the 1986-87 school year are $59 for five mornings, $36 for three mornings, and $24 for two mornings. There is also an eight-week summer program.

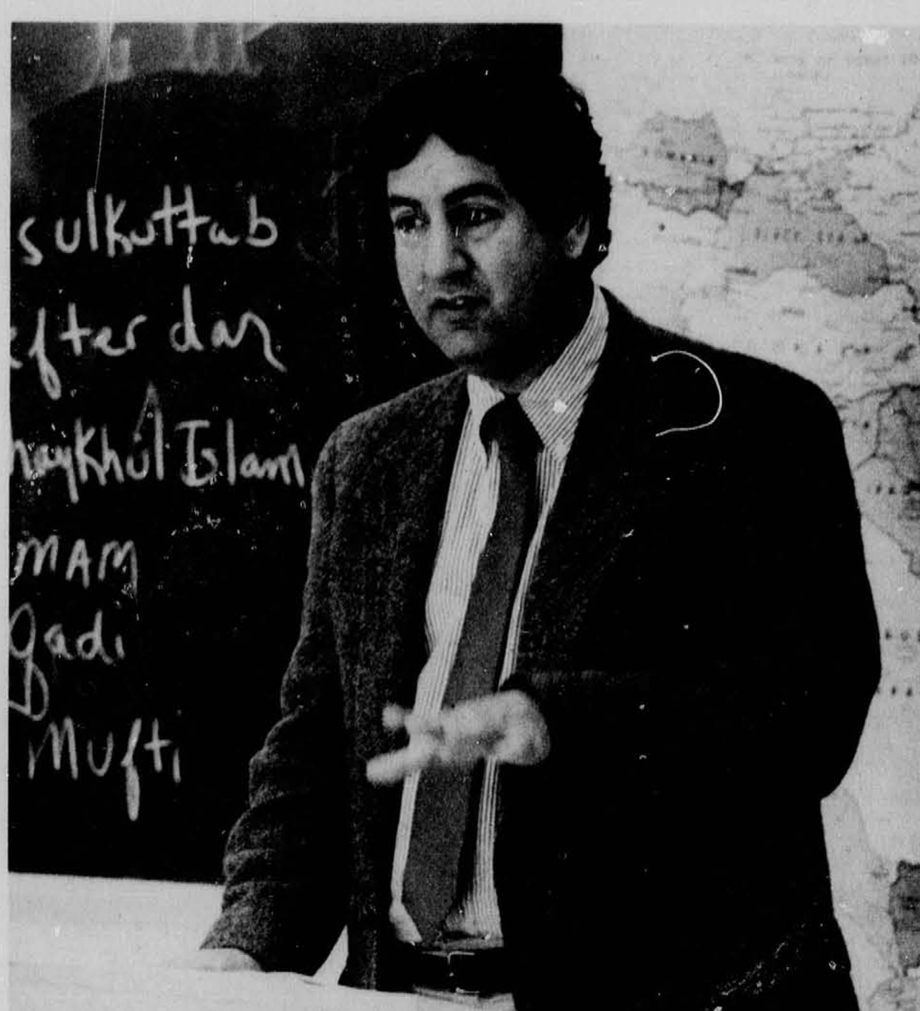
The Day Care program offers full-time, year-round care from 8 am to 5:30 pm, Monday through Friday. The center is located at Eastgate. The weekly fee for 1986-87 is $112.

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.





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. As undergraduates, students 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, 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 seminars, field trips, lecture and film series, and other activities which 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 (the General Institute Requirements), and then go on to major in one of the engineering fields, in the physical or life sciences, in management, in architecture or urban studies and planning, or in an area in the humanities or social sciences. In the first year, most 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 which they selected as their major Course of study.[1] In addition to departmental programs, it also is possible to study and even major in one of a growing number of interdepartmental fields, such as environmental or energy studies, biomedical engineering, communications science, humanities and engineering, and humanities and science.

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 I and Course I-A are curricula in Civil Engineering; 1.05 indicates a subject given in Civil Engineering. The Department of Civil Engineering as a whole is also referred to as Course 1 or Course I.

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.

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 which 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 fulfill the Institute degree requirements (listed later in this chapter), those freshmen following the more traditional subject-by-subject format may choose one of three 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 typical program for the first year includes two terms of physics, two terms of calculus, two terms of humanities, one term of chemistry, plus one or more elective subjects, perhaps including an undergraduate seminar. All subjects taken by freshmen are graded on a pass/fail basis. Some freshmen also elect to become involved in the Undergraduate Research Opportunities Program (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.

Most students build their freshman programs from among the basic subjects mentioned above. 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 place, and methods of operation. In these programs, students make progress comparable to that of 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 a 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 in the context of topics such as information theory, computation, physiological psychology, perception, the structure of history, the uses and construction of models, and the mind-body problem.

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 activity. A student may carry at least one subject per term outside the Concourse Program. Subject matter of the Concourse 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.

Concourse operates under the aegis of the Department of Electrical Engineering and Computer Science. The program supervisors for 1986-87 are Professors Jerome Y. Lettvin and David Adler. 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 is a freshman program open to about 50 students and conducted by a group of faculty from the Schools of Science and Engineering and from the Program in Science, Technology, and Society.

Its goals are two-fold: to provide for a group of freshmen an educational setting which emphasizes the connections of the scientific disciplines with their cultural contexts and their applications to human needs, and to do it in surroundings which allow the participating students and faculty to develop the sense of a shared intellectual experience.

In particular, the program will include the material in physics, chemistry, calculus, and the humanities generally expected in the freshman year. The academic disciplines are taught rigorously to bring out their internal logic and their coherence. Integration is achieved by careful scheduling so that related concepts in different disciplines are presented at the same time. It is achieved as well through seminars and through synthesis-oriented term papers and design assignments. For example, students study calculus and Newtonian mechanics along with the history of 17th-century science and with the design of early machines, and later they explore how the engineering profession developed.

Special provisions for individual advanced study are made for students who enter with degree credit in one or more of the first-year subjects. Students may also carry at least one subject per term outside the Program.

Subject matter of the Integrated Studies 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 mix of several opportunities — formal course work, seminars, discussions, a common room reserved exclusively for the Program, and the easy access to faculty and student tutors — provides a setting in which students can discover both the coherence and the diversity of the disciplines they study, and can find a congenial atmosphere of mutual support.

A detailed description of the Program may be found in the *Freshman Handbook* or by writing to the Integrated Studies Program, MIT, Room E51-017, Cambridge, MA 02139.

ESG (Experimental Study Group)

ESG is a small academic community at MIT which offers a comprehensive alternative 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 receive more personal attention and ask more questions 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 solid 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, 25 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 between 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/fail 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. At the middle and end of each term the 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. 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. Petitions for individual exceptions should be submitted to the Committee on Academic Performance. However, the Committee enforces the credit limit rigidly and only allows exceptions on purely technical grounds.

Many entering students have a well-defined 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 to them. They are also urged to select electives which will help them in deciding about their future careers. 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.

Each of the 21 undergraduate Courses combines 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.

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 which students should discuss in depth with their advisor.

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

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. The study of a language may be started or continued. Freshmen should select electives that best suit their individual needs.

Undergraduate Seminars

The Undergraduate Seminar Program offers students an opportunity to interact closely with faculty members on topics which are of current interest. 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 *Undergraduate Seminar Program* booklet, published twice yearly. Copies of the current booklet 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 which 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 department 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 a petition which indicates the desire to work for two degrees and which has been approved by faculty advisors in each of the two departments concerned at least two full terms before the student would normally receive the second of the two S.B. degrees. The requirements of each department must be satisfied and the combined program must contain at least 270 units in addition to the General Institute Requirements (a total of at least 450 units for classes entering prior to September 1986). 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 office at any time, Room 20B-141, (617) 253-5049 for advice, consolation, or congratulations.

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, and the Program's perspectives have significant implications for any course of inquiry.

The faculty members involved in the Women's Studies Program are Dr. Ruth Perry, Program Director and Senior Lecturer in Literature and Women's Studies; Dr. Evelyn Fox Keller, Visiting Professor; and 20 faculty drawn from all areas of the Institute, offering subjects in the Departments of Linguistics and Philosophy, Brain and Cognitive Sciences, Biology, Architecture, and Humanities. There also are opportunities to pursue gender-related topics in

Urban Studies and Planning; Management; the Program in Science, Technology, and Society; and the Undergraduate Seminar Program. Women's Studies offers distribution subjects as well as a field of concentration under the Humanities, Arts, and Social Sciences Requirements. The 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. Outside the Research Room is a small lounge area, available during Hayden Library hours, where members of the community can meet and exchange ideas. 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 Dr. Ruth Perry, Director, 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 three faculty/student committees: the Committee on Preprofessional Advising and Education, the Premedical Advisory Council, and the Prelaw Advisory Council.

Premedical Education

Each year nearly 10 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 Preprofessional Advising and Education, Room 12-170, (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 in the Preprofessional Office 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 during their junior or senior year.

The Preprofessional Advising and Education 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. The *Handbook* contains information on the selection of law schools, the admissions decision process, and the wide range of roles for lawyers. Copies of this and other helpful publications are available in the Office of Preprofessional Advising and Education. 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

Three branches of the military operate Reserve Officer Training Corps programs at MIT.

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 advance 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. 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 take a writing composition course and one year of a foreign language.

Eligibility Requirements

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

Application Procedure

Eligible freshmen can sign up for the AFROTC Program by registering for Aerospace Studies courses (AS11 and AS111). Incoming freshmen are advised to 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, 20E-111, MIT, Cambridge, Massachusetts 02139, or by calling (617) 253-3755. The director of the program is Colonel Emmanuel J. Scivoletto, 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. Non-scholarship 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 non-citizen 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 the Army ROTC Department, 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.

Naval ROTC Program

The purpose of the Naval ROTC program is to provide instruction and training in essential 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 to commissionees include nuclear propulsion training, submarine, surface or flight training, 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 or four years. All scholarship students incur a four- or five-year active duty obligation depending on duty option.

The College Program consists of both the four- 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.

NROTC Navy-Marine Corps College Program students may gain scholarship status by competing for a Chief of Naval Education and Training scholarship. College Program students may apply after completion of at least one semester. Competition is annual, and nomination is obtained through the Professor of Naval Science.

Two-year Scholarship and College Program students attend the six-week Naval Science Institute at Newport, Rhode Island, prior to beginning the junior year. This is to bring 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 student is commissioned as an Ensign, US Navy or Second Lieutenant, USMC, in the case of Scholarship Program students, and as Ensign, US Naval Reserve or Second Lieutenant, USMC Reserve in the case of College Program students. All newly commissioned officers report directly to active duty. Upon completion of the active duty period, 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.

Study at Other Universities

Available Programs

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 Office of Naval Science (outlined below). The second aspect consists of the academic subjects taught by the Institute. In addition to recommended course work, one year of calculus and physics and one term of an Indo-European or Asian language are required. The third aspect consists of the professional training gained from leadership laboratories (three hours a week throughout the year), from tours conducted to local naval facilities, from short cruises aboard naval vessels, and from practical navigation and piloting practice conducted aboard training craft at Newport, Rhode Island.

Students entering their sophomore year, who are eligible for the four-year College Program, 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 (none of which gives MIT credit). 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 (8 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.

Application Procedure

Further inquiries should be addressed to the Commanding Officer, NROTC and Naval Administrative Unit, 20E-125, MIT, Cambridge, MA 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) 253-4735. 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 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.

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 studies 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 which 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.

Those students interested in these programs should consult the Office of Career Services, Room 12-170, (617) 253-4735.

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 Undergraduate Office.

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 12 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 40 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 two weeks 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) a course is designated mandatory "credit/non-credit" by Wellesley, 2) they are freshmen under MIT's "pass/fail" requirement, or 3) they are juniors or seniors using one of their two MIT electives for pass/fail. Under Wellesley's credit/non-credit 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 below.

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 Ruth Spear in the Humanities Undergraduate 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.

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.

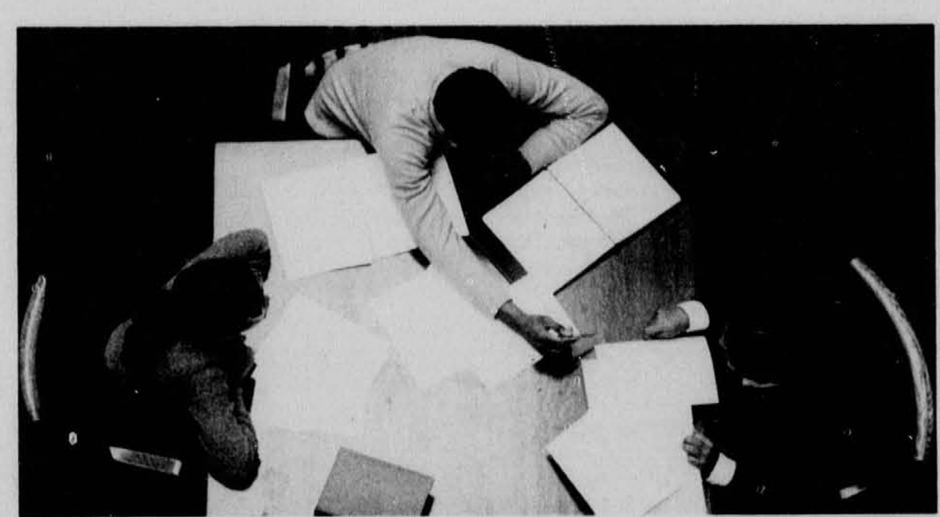
Students may take physical education classes at Wellesley on a space-available basis and may apply these classes toward their MIT physical education requirements.

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

The following areas of study are available at Wellesley:

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

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 7-108, (617) 253-1668. The Exchange Office at Wellesley is located in Room 341A, Green Hall, 235-0320 x2321 (through the MIT tie line: 187-2321).



General Institute Requirements

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. Students must have satisfactorily completed programs of study approved in accordance with the rules and regulations of the faculty, including General Institute Requirements 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 the Departmental Degree Programs chapter of this catalogue.

To be recommended for the degree of Bachelor of Science, students must have satisfactorily completed the General Institute Requirements (including the Writing and Physical Education requirements) described on the following pages, and Departmental Program requirements. Some changes have been made recently in the 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 (18.001 or 18.01 or 18.011 or 18.012 and 18.002 or 18.02 or 18.021 or 18.022)	5 subjects
Humanities, Arts, and Social Sciences Requirement	8 subjects
Science Distribution Requirement	3 subjects
Laboratory Requirement	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]

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.

Writing Requirement

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. The sequence 8.01-8.02 is the "standard" combination. A majority of students find this 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 to follow through the whole of any of the above sequences as a package, should some other choice become more suitable. There are many possibilities for switching from a first-term subject in one sequence to a second-term subject in another. In particular, there is a single second-term subject, 8.021, suitable for students who (whether or not they plan to take further physics) wish to study a broader range of topics than is available in 8.02 or 8.022.

Calculus

The Department of Mathematics offers three standard calculus sequences: 18.01-18.02, 18.011-18.021, and 18.013-18.023. 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 and 18.013 assumes some background in calculus).

A fourth 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 upon taking 18.01 or 18.013. However, for students taking 18.011 or 18.012, it will be replaced by six units of elective credit.

The primary objectives of this General Institute Requirement are: to ensure minimum standards of writing proficiency for all undergraduates, with special emphasis on writing in students' professional fields, and to see that clear, effective writing is valued and fostered throughout the curriculum as an important part of an MIT education.

The basic features of the Requirement are early evaluation, a variety of modes of completing the Requirement, and Institute-wide involvement. The Requirement is to be satisfied in two phases: **Phase One** is concerned with basic expository writing competence 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.

b) passing the Freshman Essay Evaluation during Residence/Orientation Week. For certain designated students 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, or 21.730 Expository Writing, 21.731 Writing and Experience, 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 five-page paper of expository prose written for any MIT subject and judged satisfactory by the professor of the subject and by faculty evaluators for the Requirement. Papers for any given semester will be accepted until the end of the fifth week of the following term.

Students normally complete this stage by the end of the freshman year.

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 should be satisfied by the end of the junior year.

Options for completing this phase are:

a) receiving a grade of B or better for the quality of writing in a cooperative subject within the general area of a student's professional field. Many engineering subjects (especially in laboratory and design) include instruction by Writing Program faculty. Such cooperative arrangements provide opportunities for satisfying Phase Two.

   This phase can also be satisfied by 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.

b) submitting a 10-page paper of expository prose from any MIT subject or UROP activity within the general area of a student's professional field which is judged satisfactory by the professor or supervisor and by faculty evaluators for the Requirement.

Students submitting papers must first pick up a cover sheet from the office of the Committee on the Writing Requirement (Room 7-145) 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 Committee on the Writing Requirement has published a brochure on the Requirement and resources which may be used to satisfy it. Copies of this brochure and other material are available from Bonnie Walters, Coordinator of the Committee on the Writing Requirement, Room 7-145, (617) 253-3039.

Humanities, Arts, and Social Sciences Requirement

MIT provides a substantial and varied program in the humanities, arts, and social sciences which forms an essential part of the education of every undergraduate. Through this program, students can deepen their knowledge in a variety of cultural and disciplinary areas and can develop 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) skill 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 our society; 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 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. At least three of the eight subjects must be chosen from a specially designated list of humanities distribution subjects. The three subjects are to be selected from three separate fields from the following list 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 field may be counted also as one of the required concentration subjects in the same field 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 and Archaeology
Drama
Economics
Film and Media Studies
Foreign Languages and Literatures
History
History of Art and Architecture
Labor in Industrial Society
Latin American Studies
Linguistics
Literature
Music
Philosophy
Political Science
Psychology
Russian Studies
Science, Technology, and Society
Traditions and Texts
Urban Studies
Visual Arts 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 Undergraduate Office.

HASS Information

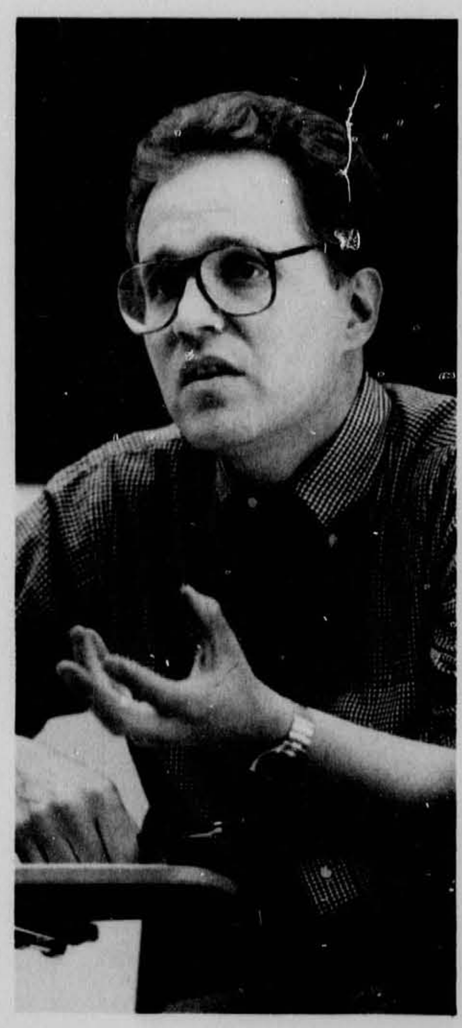
For detailed information on distribution subjects or on the concentration requirements in any field, and for assistance with any aspect of the Humanities, Arts, and Social Sciences Requirement, students should visit the HASS Information Center, Room 14N-409, (617) 253-4441.

Distribution Subjects

Humanities 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, or 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. The character of such subjects varies from field to field, and each field has established criteria for the selection of Humanities distribution subjects. These criteria have been published, along with a guide to Humanities distribution subjects, by the Humanities, Arts, and Social Sciences Information Center.

Almost all of these 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 the 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 field be counted toward both distribution and concentration.



The following is the list of subjects offered for **humanities distribution** credit:

American Studies

21.103J Literature, Ideology, and National Experience in the US [STS 601J]

Anthropology and Archaeology

21.50 Introduction to Anthropology
21.501 Understanding Other Peoples
21.502 Culture, Nature, and Human Nature
21.503 Introduction to Archaeology: Paths to Civilization
21.513 Religious Movements and Social Change
21.523 Agrarian Society
21.530J The Contemporary Family [SP 456J]
21.540 Technology and Culture
21.542 Culture and the Visual Arts

Economics

14.71 Topics in Economic History

Film and Media Studies

17.707 Mass Communication and American Culture
21.031 The Film Experience

Foreign Languages

21.203 French III
21.204 French IV
21.233 German III
21.234 German IV
21.256 Classical Greek II
21.263 Russian III
21.264 Russian IV
21.277 Spanish III
21.278 Spanish IV
21.282 Spanish for Bilingual Students

History

21.350 The Ancient World I: Greece
21.351 The Ancient World II: Rome
21.352 The Middle Ages I
21.353 The Middle Ages II
21.356 History of the Western World I: 1500-1815
21.357 History of the Western World II: 1815-1970
21.369 Marx, Darwin, and Freud
21.376 Imperial and Revolutionary Russia: Culture and Politics
21.377 The Soviet Union: A Communist Society in Historical Perspective
21.390 American History to 1865
21.391 American History Since 1865
21.409 American Ideas and Culture: From the Puritans to the Civil War
21.410 American Ideas and Culture: From the Civil War to WWI
21.411 American Ideas and Culture: The Modern Age, 1920-1980
21.416J American Women's History [SP 420J]
21.435 The American Psyche
21.450 The History of Africa
21.451J The History of 20th-Century Africa: Nationalism and Nation-Building [17.551J]
21.460 East Asian History: China
21.461 East Asian History: Japan
21.480 The Middle East: From the Rise of Islam to World War I
21.481 The Middle East in the 20th Century

History of Art and Architecture

4.601 Topical Studies in the History and Theory of Art
4.605 Introduction to the History and Theory of Architecture
4.635 Renaissance Architecture
4.642 Modern Art from Impressionism to Cubism
4.651 Modern Art from Cubism to the Present

Labor in Industrial Society

14.63 Labor in Industrial Society

Linguistics

24.900J The Study of Language [21.321J]

Literature A[1]
(Read in English)

21.001 Foundations of Western Literature: Homer to Dante
21.002 Classics of European Literature
21.003 Introduction to Fiction
21.004 Introduction to Poetry
21.005 Introduction to Drama
21.006 Introduction to American Literature
21.009 Shakespeare
21.010 Literature and Film
21.021 Comedy
21.022 Tragedy
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]
21.300J Courtship Themes in Romance Literature [SP 434J]
21.303 Twentieth-Century French Literature
21.310 Masterpieces of the Hispanic Tradition
21.314 Slavic Civilization: Gods, Demons, and the Supernatural
21.315 Russian Short Story
21.317 Russian Novel of the 19th Century
Wellesley Italian 211: Dante

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

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

21.209 French Civilization
21.211 Introduction to French Literature
21.217 Introduction to French Poetry
21.218 Introduction to the French Short Story
21.221 French Romanticism
21.224 Artistic and Intellectual Currents of Modern France: Literature and Ideology
21.225 Representations of Love in French Literature
21.239 Introduction to German Literature
21.240 German Culture and Society: 1750-1914
21.241 Fantasy and Reality in 19th-Century German Literature
21.243 German Short Fiction
21.249 Introduction to German Poetry
21.250 Introduction to German Drama
21.268 Topics in Russian and Soviet Culture for Bilinguals
21.270 Pushkin and his Successors
21.284 Introduction to Latin American Culture
21.285 Introduction to Spanish Culture
21.286 Latin American Literature 1492-1898: Creation of a Continent
21.287 Twentieth-Century Latin American Literature: The Alchemist's Laboratory
21.290 Literature and Social Conflict: Perspectives on Modern Spain

Music

21.60 Introduction to Music
21.621 Western Music to 1750
21.622 Western Music after 1750
21.625 Vivaldi, Bach, and Handel
21.631 Symphonic Music
21.635 American Music
21.636 Jazz
21.637 Traditional Music in America

Philosophy

24.00 Introduction to the Problems of Philosophy
24.01 Contemporary Moral Issues
24.02 The Meaning of Life
24.03 Logic, Language, and Values
24.04 Moral and Legal Responsibility
24.05J Nature of Scientific Knowledge [STS 205J]
24.08 The Human Mind
24.09J Classics in Political Philosophy [17.113J]

Political Science

17.103 Socialism
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
17.401 Just Wars, Total Wars, and Nuclear Wars
17.403 American Foreign Policy in a Changing World
17.501 The Quest for Equality and Development in Third World Countries
17.543 Political Change in Latin America
17.549 Political and Economic Development of Tropical Africa
17.585 Religion, Politics, and Social Change in Developing Countries

Religious Studies

Wellesley Religion 107: Crises of Belief in Modern Religion
Wellesley Religion 108: Introduction to Asian Religions
Wellesley Religion 252: The Islamic Tradition

Sociology

Wellesley Sociology 102: The Sociological Perspective
Wellesley Sociology 103: Social Problems

Science, Technology, and Society

STS 101 The Development of Science in the 16th to 18th Centuries
STS 102 Science, Technology, and Social Change
STS 200 The Scientific Revolution
STS 201 History of 19th- and 20th-Century Science
STS 210 American Science Since the 1930s
STS 300 History of Technology in America I: 1787-1876
STS 301 History of Technology in America II: 1876-the Present
STS 320 Arms, Power, and the Engineer
STS 321 Military Enterprise and Technological Change: Historical Perspectives on the American Experience
STS 502 The Profession of Engineering
STS 511 Capitalism and Its Critics
STS 600 Technological Society and Its Critics
STS 602 Perspectives on Technology

Traditions and Texts

21.708 The Bible
21.709 The Greeks
21.714 The Renaissance and Reformation
21.717 The Modern Period: 1900-1970
21.718 The Americans

Urban Studies

11.005 Urban Social Structure and Process
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]
11.131 The Urban Neighborhood
11.165 Law and Public Policy

Visual Arts and Design

4.802 Visual Form and Expression
4.901 Creative Seeing

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.

	Women's Studies
SP 401	Introduction to Women's Studies
	Writing
21.735	Writing and Reading the Essay
21.755	Writing and Reading Short Stories
21.760	Writing and Reading Poems
21.777	The Scientific Essay
	Interdisciplinary Subject
21.930J	Ancient Cosmology [STS 223J]

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 Undergraduate Office, Room 14N-409.

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 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)
6.524J	General Physiology (3-0-9)
7.01	General Biology (4-0-8)
7.05	General Biochemistry (5-0-7)
7.51J	General Physiology (3-0-9)
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)
8.291J	Planetary Science I (3-0-9)
8.292J	Planetary Science II (3-0-9)
8.293J	Dynamical Astronomy (3-0-9)

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

10.11 Computer Models of Physical and Engineering Systems (3-0-9)
10.13 Mass and Energy Processing (4-0-8)
12.01 Geological Processes, Features, and History (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)
12.115J 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 (3-0-9)
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)

Laboratory Requirement

The Laboratory Requirement of one subject of at least 12 units or two subjects of at least 6 units is to be 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, to provide broad coverage of a particular field, or to 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.

1.101 Decision Analysis Laboratory (0-3-3)
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 (2-3-4)[1]
2.672 Project Laboratory (1-3-2)
2.86 Manufacturing Processes and Systems (3-3-3)[1]
3.081 Materials Laboratory (2-6-7)
4.071J Design with Microclimate (3-6-3)
4.315J Structural Engineering Laboratory (0-3-3)
5.310 Laboratory Chemistry (2-8-2)
5.311 Introductory Chemical Experimentation (2-8-2)
6.101 Introductory Electronics Laboratory (3-8-1)
6.111 Introductory Digital Systems Laboratory (3-7-2)
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 (2-8-4)
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 Psychology (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 Evaluation Research Laboratory (3-5-4)
20.002 Laboratory in Applied Biology (2-8-4)
22.069 Undergraduate Plasma Laboratory (1-8-3)
22.09 Introductory Nuclear Measurements Laboratory (2-6-4)

1
Students taking 2.671 or 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. A student by then 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 class. Credit may be gained by participation in the intercollegiate program (four points for each sport in season). A maximum of four points (two points per year) may be gained 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. Transfer students beyond the sophomore year are *not* subject to the requirement.

The program consists of both individual and team activities with the major emphasis placed on the development of skills which 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.

Independent Activities Period

Program Information

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 du Pont Gymnasium on the day of or the day after the academic registration and on a specific date halfway through each semester.

First Quarter:
Archery, bicycling, ballet I, II, jazz, exercise for body conditioning, partner dance, introduction to dance, touch football, ultimate frisbee, golf, lacrosse, pistol, rugby, sailing, scuba, sculling, exercise fitness, swimming (beginning), T'ai Chi, tennis (beginning and intermediate), weight training, and yoga.

Second Quarter:
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), weight training, and yoga.

IAP:
Badminton, baseball (hitting), aerobic dance, ballet I, jazz, partner dance, fencing, applied fitness, hockey, box lacrosse, pistol, exercise fitness, skating (beginning), figure skating, squash, tennis (intermediate and advanced).

Third Quarter:
Basketball, ballet I, II, jazz, exercise for body conditioning, partner dance, fencing, figure skating, hockey, judo, karate, pistol, scuba, exercise fitness, skating (beginning), skin diving, squash, swimming (beginning, advanced beginning, and advanced techniques), volleyball, weight training, and Red Cross advanced lifesaving (part 1).

Fourth Quarter:
Archery, ballet I, II, jazz, partner dance, exercise for body conditioning, ultimate frisbee, lacrosse, golf (beginning), pistol, sailing, scuba, sculling, exercise fitness, softball, squash, swimming (beginning and advanced techniques), tennis (beginning and intermediate), weight training, and Red Cross advanced lifesaving (part 2).

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 which 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 in which faculty members and students are freed from the rigors of regularly scheduled classes to provide time for flexible teaching and learning and for independent study and research. Students are encouraged to explore the educational resources of the Institute not only by individually arranging projects with faculty members but also by organizing and participating in special IAP activities. Or they may pursue interests independently either on or off campus.

Although IAP is kept as unstructured as possible, it is part of the academic program of the Institute — the "1" in MIT's "4-1-4" academic calendar. Grades are deemphasized during IAP. However, students may earn academic credit for work directed by a faculty member.

Activities

More than 600 activities are offered each year on a wide range of subjects, both academic and nonacademic. IAP activities are organized mostly by individual volunteers only one or two months in advance. They 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 teach and to develop 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

Most activities do not offer credit. However, it is possible for a student to earn academic credit by doing work under the direction of a faculty member for a subject listed in the Bulletin. 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

Admissions

Freshman Admissions

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 Ronald P. Smith, 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 7-108, (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.

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 is available with 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 (Interview)

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 students make a successful transition from high school to the pace and style of MIT, a special summer session is available, called Project Interphase. This program offers subjects in math, science, and the humanities which build on the regular entrance requirements. It is available by invitation at no expense to the student.

International Undergraduate Admissions

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) G.C.E. 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 in 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. The students are notified of the credit offered before registration so that they may discuss an optimum schedule with their faculty advisor.

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.

Entrance Examinations

All candidates are required to take the following tests given by the College Board: the Scholastic Aptitude Test 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.)

The College Board offers these examinations in the principal cities of the United States and abroad. The test dates, locations, and fees for the current year are outlined in an Information Bulletin which 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.

Candidates for admission for September 1987 must have completed the SAT and the three Achievement Tests by the January 1987 testing date. Either the SAT 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 College Board 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

MIT requires a complete set of application materials before considering a candidate for admission. A student who takes all the required College Board 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 to complete 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. Included in the response will be the leaflet, "Information for Prospective International Students" and 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 College Board tests (including, if appropriate, the Test of English as a Foreign Language — TOEFL) must be taken 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, a representative of the Institute for International Education, or the America-Mideast Educational and Training Services (AMIDEAST).

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.

College Transfer Admissions

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 the Physics Achievement Test, the Chemistry or Biology Achievement Test, 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.

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.

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 College Board 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. These forms should be sent directly to the Director of Admissions by the endorsers.

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
College Board 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.

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 1986-87 at MIT will be about $17,700. 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 $1,550. 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 $4,350 for room and board. Thus, total costs for most undergraduates during the 1986-87 academic year will be in the range of $16,600 to $19,500 (excluding cost of travel), depending upon specific choices.

The following are the basic **tuition and fees** at MIT for the academic year 1986-87 (which are reviewed and likely to increase each year):

Tuition	$11,800
Hospital and Accident Insurance Policy[2]	276

The tuition for all regular undergraduates in the first and second terms is $5,900 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.

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 pre-entry medical forms, administration of pre-entry 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 $864. Hospitalization insurance for one or more children may be purchased for $276. 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.

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 $190 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 $1,140 for subjects and a minimum of $490 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 $190 per unit taken either for credit or not for credit. This unit fee applies up to a maximum of $5,900 per term and is subject to the following minimum fees:

Members of the MIT Community[3]	$1,140
Other Special Students	1,710

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
Mechanical Engineering, Course II-B
Ocean Engineering, Course XIII-C
June-August (15 months), $11,800

Electrical Science and Engineering or
Computer Science and Engineering,
Course VI-A
Engineering Internship Program
July 1 to June 30, $11,800

Materials Science and Engineering,
Course III-B
September-August, $11,800

In each case, the first $5,900 is due on the date when the first-term tuition is normally due, and the additional $5,900 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.

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

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 or Graduate Registration Officer 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	20
Fee for late filing of degree application	20

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 $20 for one subject or $25 for more than one subject in a petition. There is an additional charge of $20 for a retroactive change after the end of the term.

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

Payments

Financial registration forms and instructions, and bills for tuition and other charges will be sent to admitted and continuing undergraduate students prior to the beginning of each term. Students must, by the due date specified in these instructions, either make their payment in full or elect the MIT Bursary Payment Plan, which allows for monthly payments plus applicable finance charges.

If the Bursary Payment Plan is elected, it must be signed by the payment due date to avoid the late payment charge. Students not on the Bursary Payment Plan will be assessed a late payment charge of one and one-half percent on the outstanding balance of their accounts each time a payment due date is missed.

All outstanding bills must be paid, or satisfactory arrangements made with the Bursar for their payment, before a student will be allowed to register at the beginning of a term, or, if a candidate for a degree, be allowed entry of his or her name on the degree list.

Registered student status can be withdrawn at any time for delinquency in payment of bills.

To assist students in meeting each term's expenses, various financial aids are available for which the student may be eligible (described in the next section). Students and their families might also consider the installment plans that are offered. The MIT Parent Loan Plan, for example, is designed to help parents who are US citizens pay for four years of college costs over a period of about seven years. MIT provides the basic funds for this monthly installment plan, which offers loans at moderate interest rates to parents whose annual family income is between $25,000 and $125,000. There are also a number of prepayment plans and extended payment plans available through commercial banks, lending institutions, and insurance agencies. Information on these installment programs will be sent in the spring to the parents of newly admitted students. Otherwise, information may be obtained from John Rogers, MIT Parent Loan Plan Office, Box 160, Boston, Massachusetts 02101, (617) 253-4134.

Financial Aids

Grants, Loans, and Employment

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 400 such scholarships from which student aid is annually drawn. Additionally, there are about 40 loan funds which 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 which is not met by a grant may be offset by long-term loans or employment.

Students are expected to work and/or borrow as the first incremental portion of their aid. 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 only on the basis of demonstrated financial need. Undergraduate loans are provided from several sources, including the National Direct Student Loan (NDSL) Program, the Guaranteed Student Loan (GSL) Program, and the Institute's own Technology Loan Fund.

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.

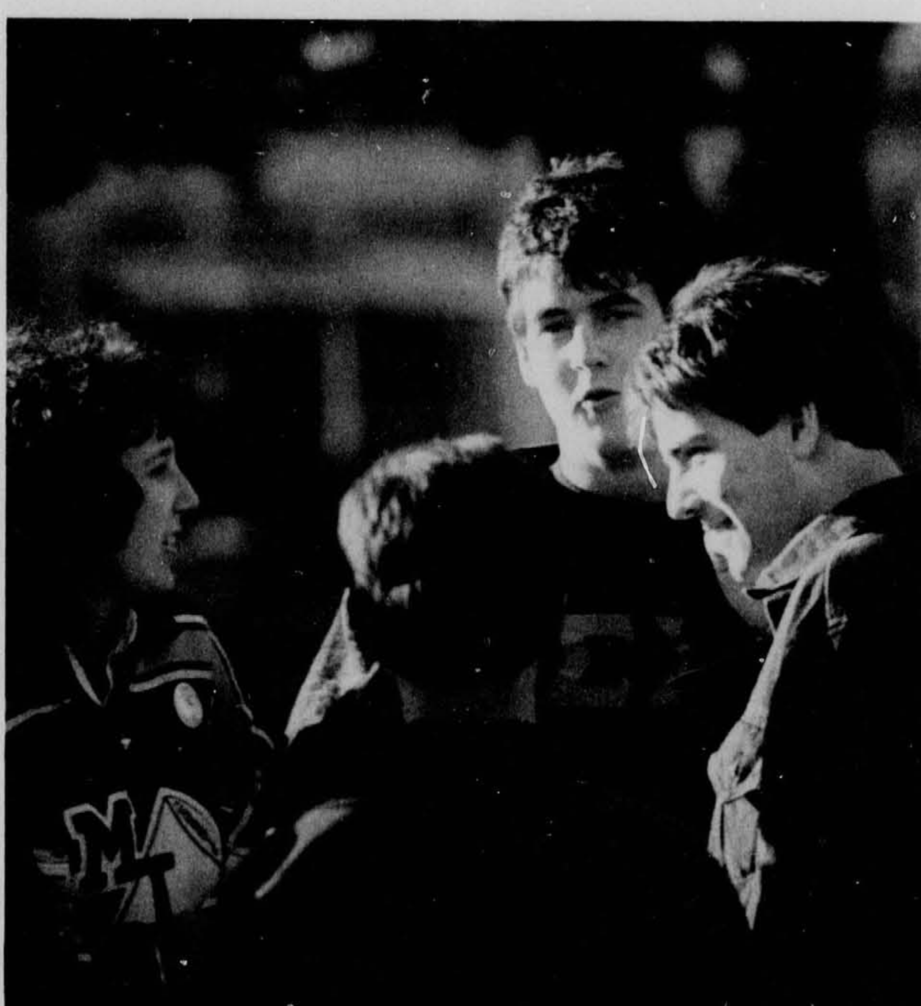
Applications for Financial Aid

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 explore the Institute's Parent Loan Plan, which is described in the preceding section.

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 which 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 November 1. 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.

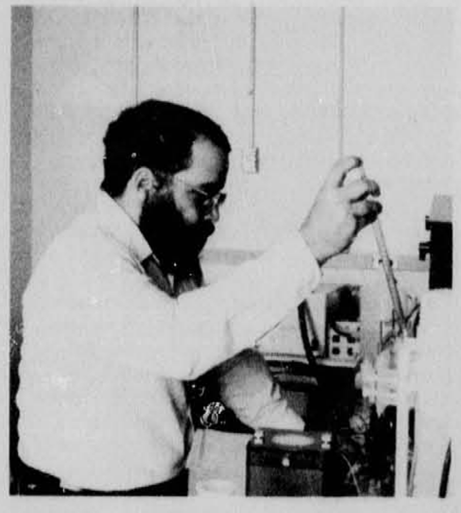
Upperclass Students

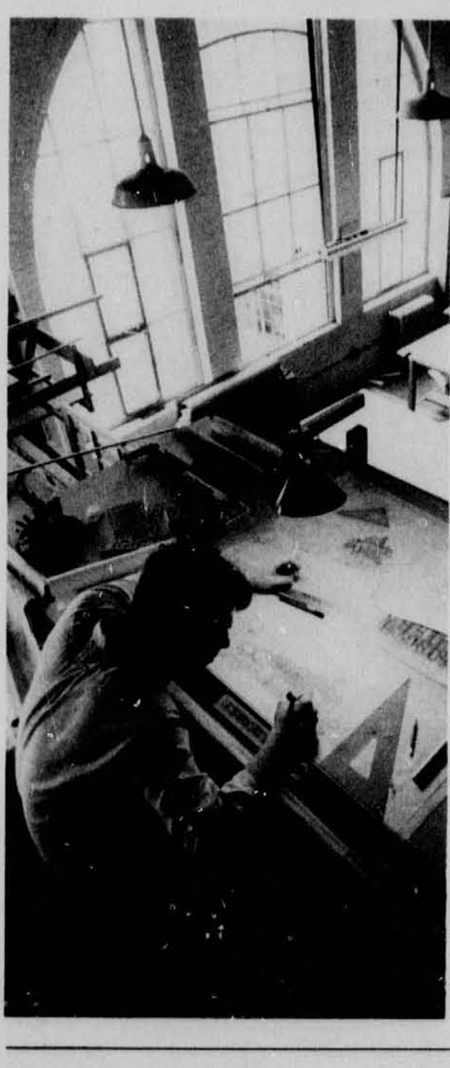
MIT awards are made on an annual basis, and recipients are required to reapply each year for continued assistance in the following year. Upperclass financial aid applications are sent to the term addresses of current aid recipients in early February; upperclass students who have not been receiving assistance may also apply at this time by obtaining the new forms from the Student Financial Aid Office. Part of the application process involves providing 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 which 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, 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. Although MIT has always welcomed women graduate students, the last 15 years have seen an increase in the number of women attending MIT's graduate programs, particularly those in nontraditional fields of study. This broad representation of students from diverse backgrounds has contributed 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 interdisciplinary 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 in which 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 undergraduate and graduate students participate in intercollegiate competitions, and the intramural athletic program.

Graduate students are welcome to 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.

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.

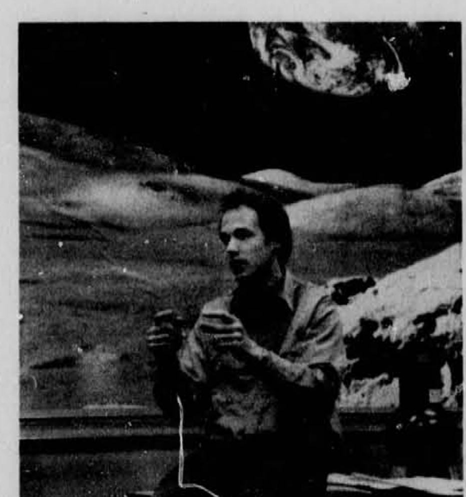
Graduate students should read the section on IAP in Chapter III of this catalogue for details concerning credit, VA benefits, and special student status.

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 Deans 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 which 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 "résidence" 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 which, 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

Engineer's Degrees

(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 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.

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, psychology, urban studies and planning, and 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; 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 which are not offered at the student's own institution. Students will not be allowed to attend classes in which 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.

Admissions

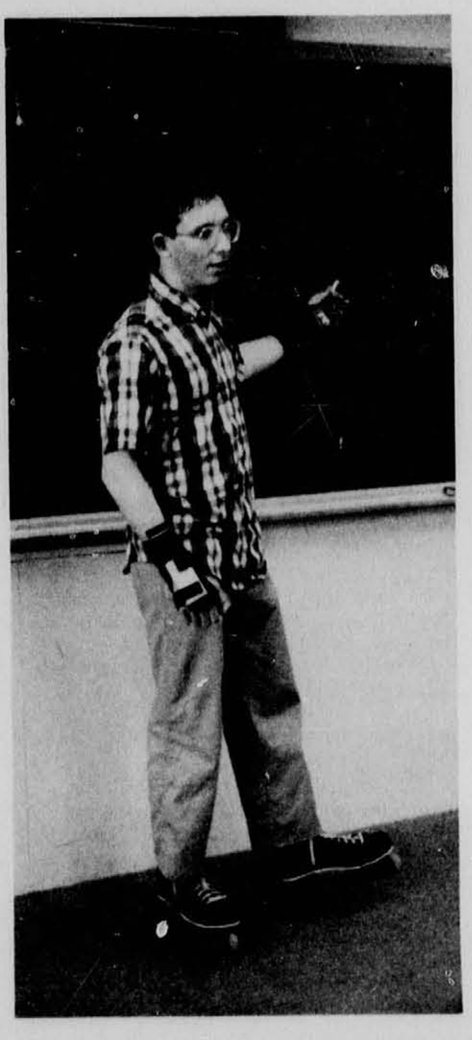
Regular Graduate Admissions

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 the MIT Department of Applied Biological Sciences and the School of Dental Medicine at Tufts University. The program is restricted to specific graduate subjects at each institution.



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 mathematics and physical science. 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 14; candidates for admission in February should apply by November 1. However, applications submitted later may be considered if vacancies still exist. 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 (except to the Sloan School of Management and the Departments of Chemistry, Urban Studies and Planning, and Physics) should usually be requested from and submitted to the Director of Admissions, Room 3-103, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139. A $40 application fee (except for the Master's Program in the Sloan School) must accompany all application forms. Payment should be made by check or money order, payable to the Admissions Office, MIT. 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. Applicants are urged to consult with appropriate departments to confirm test requirements and recommendations. 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. 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.

Applicants must submit complete application materials to the Director of Admissions.

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 ot 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.

Citizens of countries other than the United States whose native language has not been predominantly English must submit the Test of English as a Foreign Language (TOEFL) as noted in the section on International Graduate Admissions.

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 nonresident 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 1986-87 (which are reviewed and likely to increase each year):

Tuition[1]	$11,800
Hospital and Accident Insurance Policy[2]	276

The tuition for all regular graduate students, including graduate student staff, in the first and second terms is $5,900 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 $8,850, if not registered during the preceding regular term. The tuition for all regular graduate students including fellows, trainees, and academic staff in the 1986 summer session was $3,950. 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 $190 per unit taken either for credit or not for credit. This unit fee applies up to a maximum of $5,900 per term and is subject to the following minimum fees:

Members of the MIT Community[3]	$1,140
Other Special Students	1,710

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 $490 per week from the starting date of the term, with a minimum of $490 for the Master's or Engineer's degree and $980 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 $2,950. 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 ($885 per term for 1986-87). 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 $2,950. 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-B
Mechanical Engineering, Course II-B
Ocean Engineering, Course XIII-C
June-August (15 months), $11,800

Chemical Engineering Practice, Course X-A
September-January or February-June, $5,900

Electrical Science and Engineering or Computer Science and Engineering, Course VI-A
Engineering Internship Program
July 1 to June 30, $11,800

Materials Science and Engineering Course III-B
September-August, $11,800

In each case, the first $5,900 is due on the date when the first-term tuition is normally due, and the additional $5,900 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 $325 per unit of registration, with a minimum charge of $2,925. There is a maximum charge of $9,975 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 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.

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, administration of required pre-entry 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 $864. Hospitalization insurance for one or more children may be purchased for $276. 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.

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) for a single graduate student generally average about $945; for a married graduate student, $1,280; and for a married graduate student with one child, $1,685. 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	20
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	30
All other theses for advanced degrees	20

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 $20 for one subject or $25 for more than one subject in a petition. There is an additional charge of $20 for a retroactive change after the end of the term.

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

Payments

Financial information and instructions and bills for tuition and other charges will be sent to admitted and continuing graduate students prior to the beginning of each term. Students must, by the due date specified in these instructions, either make their payment in full or elect the MIT Bursary Payment Plan, which allows for monthly payments plus applicable finance charges. Research and teaching assistants who have fees in excess of $200 billed through the Bursar's Office, after the tuition portion of their award has been credited, may pay their fees through monthly payroll deductions without associated finance charges.

If the Bursary Payment Plan is elected, it must be signed by the payment due date to avoid the late payment charge. Students not on the Bursary Payment Plan will be assessed a late payment charge of one and one-half percent on the outstanding balance of their accounts each time a payment due date is missed.

All outstanding bills must be paid or satisfactory arrangements made with the Bursar for their payment before a student will be allowed to register at the beginning of a term, or, if a candidate for a degree, be allowed entry of his or her name on the degree list.

Registered student status can be withdrawn at any time for delinquency in payment of bills.

Students and their families might consider the Parent Loan Plan, developed to help parents of MIT students pay for educational expenses at MIT over an extended period of time. This monthly installment plan offers loans at moderate interest rates to parents (US citizens) whose annual family income is between $25,000 and $125,000. Further information may be obtained from John Rogers, MIT Parent Loan Plan Office, Box 160, Boston, Massachusetts 02101, (617) 253-4134.

Financial Aids

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 every 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.

Upon admission to an MIT graduate program, all students are required to complete the MIT Graduate Student Need Determination form as a part of the registration process. Although MIT does not require completion of the Graduate and Professional Schools Financial Aid Service (GAPSFAS) form, students may submit the GAPSFAS form in lieu of the MIT Graduate Student Need Analysis form. To do so, they must designate on the GAPSFAS form that a copy should be sent to MIT.

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.

A fellowship or traineeship is an award to a graduate student which covers tuition, partially or fully, and provides, in addition, a stipend to help defray living expenses. In the context of the Graduate School, a scholarship is an award which fully or partially covers tuition only. Most awards are made on the basis of academic merit and in some instances financial need to individuals who are enrolled as regular, resident students. Under Section 117 of the US Internal Revenue Code of 1954, such awards, held by degree candidates, are not usually subject to income tax.

The Institute receives funds from individual donors and corporations which provide for the support of fellowships and scholarships each year. In addition, government agencies and private foundations offer fellowships and other grants which they award either directly to outstanding students for use at institutions of their choice or, in a few cases, to MIT for award to its students.

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 14. 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 only be eligible for 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 as the Dean of the Graduate School deems appropriate.

Loan Funds

MIT administers the Technology Loan Fund under which financial assistance is available to graduate students. However, loan capital is limited and MIT student loans are granted only after the student has explored all sources of aid — including employment opportunities, the Guaranteed Student Loan program, and the Auxiliary Loans to Assist Students (ALAS) from banks and other lending institutions. Eligibility for MIT loans is based on need as determined by the Student Financial Aid Office, and is a function of student expenses and resources (including assets). Standard budgets have been developed for single students and married students with or without dependents and are rigorously applied. Loans not covered by the Guaranteed Student Loan or ALAS programs require a co-signer. State Guaranteed Loans may be approved when the student is enrolled for 24 or more units.

Graduate students who do not possess US citizenship or a permanent resident visa are not eligible for state or Federally guaranteed loans, nor are they eligible for MIT loans during the first year of residence. Thus, students who are citizens of other countries must be prepared to meet their expenses for the first year at MIT without recourse to loans from the Institute and without expectation that in subsequent years loans may be available.

Specific information on eligibility for loan funds is available from the Student Financial Aid Office, Room 5-119.

Teaching and Research Assistantships

MIT employs about 425 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 1,500 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 which 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.

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.

Other Employment Opportunities

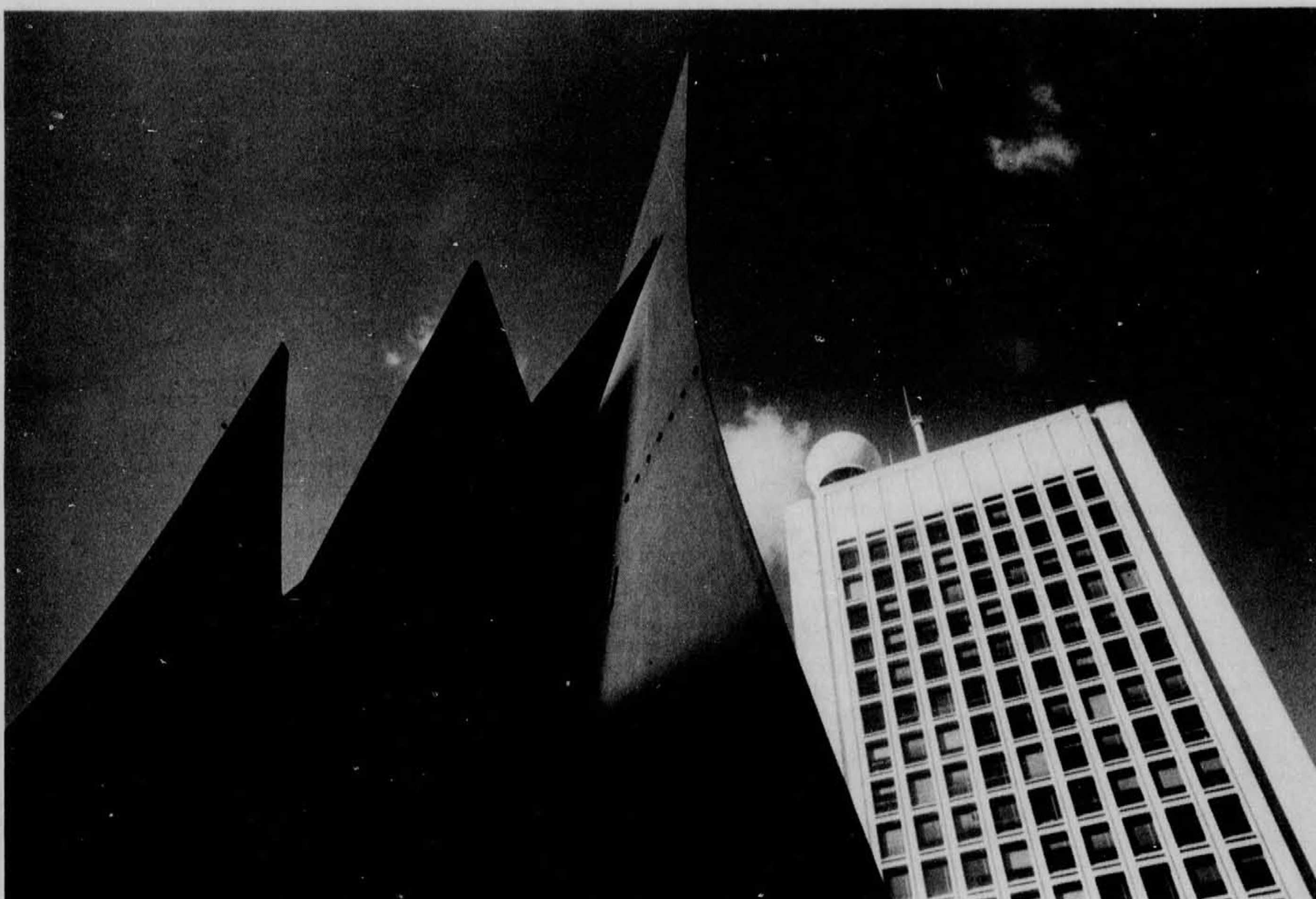
Employment is available both on or off campus. The Student Employment Office, Room 5-119, keeps up-to-date listings of job opportunities which are open to graduate students. Some positions are available directly through the academic departments, laboratories, and administrative offices on campus.

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.

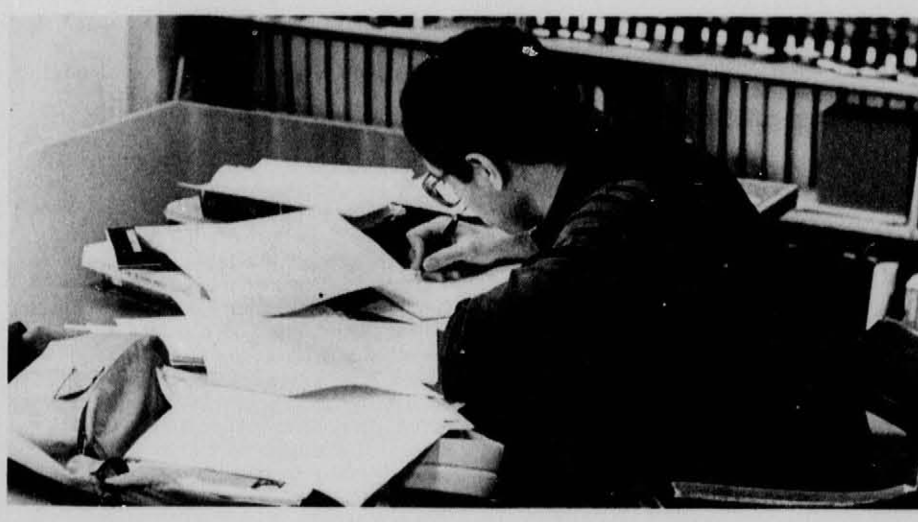
International students may work on campus but may require special permission from the US government to work off campus. Citizens of other countries should consult the Dean for Student Affairs' international student advisor before accepting employment.

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 Material" packet, 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.*

Definition of Student Status

Once admitted (or readmitted) to MIT, a person becomes an MIT student at the start of the term for which he or she was admitted. Student status is retained until graduation, unless the student withdraws, is required to withdraw, or fails to complete registration in a given term.

For the fall and spring terms, **undergraduate** and **graduate** students must complete the five steps listed below in order to continue student status during that term: 1) registration material issued by the Registrar has been completed and returned; 2) financial registration material issued by the Bursar has been completed and returned; 3) all Institute charges have been paid when due, or satisfactory alternative arrangements have been made with the Bursar; 4) the faculty advisor or registration officer has signed the student's registration form and this form has been received by the Registrar's Office; and 5) an ID validation sticker has been picked up. In addition, **graduate** students must submit the MIT Graduate Student Need Determination form (along with parental information when required). The Graduate and Professional Schools Financial Aid Service (GAPSFAS) form may be submitted in lieu of the Graduate Student Need Determination form. To do so, graduate students must designate on the GAPSFAS form that a copy be sent to MIT.

Any student who has not completed the above steps by the start of the sixth week of the term will be withdrawn and charged a prorated tuition for this period.

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, Room 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 in 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 stands in the Registrar's Office. This will confirm the student's registration and point out 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.

Academic Performance and Grades

Subject Credits and Designations

The credit hours (units) for each subject indicate the number of hours spent each week in class and laboratory, plus the estimated time which 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 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.

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 lapse to 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. 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 of $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 which 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 7-103, 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 permission to continue or may be warned that without substantial improvement in 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 foundation 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 the circumstances indicated:

S, notation for credit awarded for work done elsewhere.

SA, notation for satisfactorily completed 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. 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.

End-of-Term Regulations

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 than those mentioned above.

U, a notation for thesis work which 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.

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:

• 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 anywhere from one hour to three hours.

• For each subject which 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, 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. (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 which falls due after the last regularly scheduled meeting of the class for that subject. 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 the permission of the CAP for undergraduate subjects or the CGSP for graduate subjects. Asking students to vote on some deviation from the rules is not an acceptable procedure.

• 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.

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 the 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 may 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 within the department, a complaint against a student should 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 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 which 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 of race, color, sex, religion, 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 the established grievance procedures outlined earlier. Additional information on procedures for following up on harassment concerns is available from the Office of the Dean for Student Affairs, including a "Guide to Alternative Starting Points and Sequences 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 which 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 than $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 acknowledgement 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.

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 student 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 as explained below. 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 seven faculty members, five students, and the Dean for Student 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 Students 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 above.

The above 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 Section 503 and 504 of the Rehabilitation Act of 1973.

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 booklet on harassment entitled "Tell Someone" is also available from the Dean's Office. 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 which 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 a 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 organizations 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 take care not to encourage waivers unnecessarily.

Personal Files of Faculty and Staff

The personal files of members of the faculty and staff which 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 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.

VI

Interdepartmental Study and Research

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 dealt with 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 here and described in detail in this chapter. The specific opportunities available 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 which 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) which are offered; e.g., **(S.M.), (Ph.D.).** Other study or research opportunities **may** be fields of study which lead to advanced degrees, either as part of departmental 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
Bitter National Magnet Laboratory
Cell Culture Center
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 Health Effects of Fossil Fuels Utilization
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
Environmental Studies
ESG (Experimental Study Group)
Health Sciences and Technology
Humanistic Studies Combined with Engineering or Science (S.B. Degree Programs)
Integrated Studies 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
Lincoln Laboratory
Management of Technology Program
Materials Processing Center
Media Arts and Sciences
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
Real Estate Development (see Center for Real Estate Development)
Research Laboratory of Electronics
Research Program on Communications Policy
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
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, commonsense 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 very large-scale integrated circuit design and programming.

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 include information retrieval and intelligent support systems, both oriented toward supplying 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 a connection memory machine with a million processors and on scalable, message-oriented models of computation.

Further information is available from Professor Patrick H. Winston, Director, Artificial Intelligence Laboratory, Room NE 43-816, 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 a versatile facility for research and teaching in optical astronomy, and directly supports the growing student and faculty interest at MIT in astronomy and related sciences. 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 which is applicable to biological problems, and who intends to pursue a professional engineering career which may lie outside 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, and Nuclear Engineering.

Further information on departmental programs in the School of Engineering 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 L. R. Young, Room 37-207, MIT, Cambridge, MA 02139, (617) 253-7805. The *Guide to Biomedical Engineering and Physics at MIT and Harvard* describes both educational programs and research activities. Copies are available from Professor Young at the above address.

3) The HST Doctoral Program in Biomedical Engineering and Physical Sciences 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 engineering or physical science. The GRE aptitude test and one advanced test are also required. 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. The Committee on Biomedical Engineering serves as an advisory body which can assist students in setting up interdepartmental programs. Further information may be obtained from Professor L. R. Young, Room 37-207, MIT, Cambridge, Massachusetts, 02139, (617) 253-7805.

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 Mössbauer 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 of the Laboratory, Professor Peter Wolff, Building NW14-3220, MIT, Cambridge, Massachusetts 02139, (617) 253-5478.

Cell Culture Center

The Cell Culture Center was established in 1974 to serve as a facility and resource for cell biologists throughout the United States. Its mission is to carry out large-scale production of animal cells and their products that will allow scientists to conduct novel and important experiments in basic cell biology which could not be carried out with the materials and resources available in the investigator's own laboratory. The Center works directly with individual scientists on basic research problems, and carries out an active program for the development of new techniques for large-scale cell production. A limited number of **graduate** and **undergraduate students** can participate through the Departments of Biology or Applied Biological Sciences in studies carried out in the Center involving large-scale animal cell production. Recently a Cell Sorter Laboratory was added which provides instrumentation to analyze various light scatter properties and any compatible fluorescent label on a rapid, single-cell basis, providing statistical quantitation of each desired parameter on a given suspended cell population. The laboratory is equipped with Ortho Diagnostic Instrumentation and an on-line computer system for data acquisition, storage, and analysis.

Further inquiries may be addressed to the Office of the Director, Dr. Donald J. Giard, Room E17-321, MIT, Cambridge, Massachusetts 02139, (617) 253-6430.

Center for Advanced Engineering Study

The primary objective of CAES is to improve and extend the capabilities and effectiveness of practicing professionals in engineering and the sciences by providing high-quality learning opportunities on campus, at the workplace, and at other locations. Emphasis is given to technical and managerial-technical subjects which are applications-oriented. The Center identifies problems which are of great national or professional importance and offers instruction and assistance to the profession in solving them. Through research and improved methods of continuing education, the Center provides a number of ways for participants to acquire the knowledge and skills needed to resolve these problems.

The Center offers the following programs, which include both on-campus and off-campus activities:

1) The Advanced Study Programs enable engineers, scientists, and technical managers to come to MIT for one or more terms to work in depth and to strengthen their base in technological areas pertinent to their professions. The entire offering of MIT undergraduate and graduate subjects, seminars, and colloquia is available. Participation in ongoing research work and self-study programs can be arranged. Participants may develop programs of study to meet their individual needs or may participate in specialized programs in Air Transportation, Communication Technology and Policy, Design and Manufacturing Automation and Control, Biotechnology, Machinery Noise and Diagnostics, Quality and Productivity, and Systems Reliability and Risk Analysis. A certificate is awarded following satisfactory completion of a Program.

2) The Visiting Engineers Program enables outstanding experienced research engineers to spend an academic year or longer at MIT pursuing research in close collaboration with one or more MIT faculty members.

3) Through the Video Course Development Program, CAES has developed more than 1,000 videotapes, video course manuals, and textbooks in engineering, science, mathematics, and management. These video-based courses are designed to meet the individual needs of engineers, scientists, and technical managers working in the field. The 50 video courses are utilized by over 30,000 learners (at a distance) annually.

4) The Conference and Seminar Program supports a variety of nonaccredited continuing education programs — workshops, seminars, short courses, and conferences. Emphasis is

on technical and management applications in science and engineering, reflecting trends in the marketplace and their relationship to technology devopment. Individual programs vary in length, lasting from one day to one month, and may be held at MIT or other locations around the country and overseas.

5) This year the Center's program of research and development in continuing education shifted its emphasis from energy conservation to the problems associated with commercial competitiveness in international markets. One of the keys to increased strength in this area is increased quality and productivity. The Advanced Study Program, the Video Course Development Program, and the Conference and Seminar Program gave this topic high priority and produced new programs. The Center has been active on the national scene organizing local conferences and encouraging the formation of a network of local consortia.

For more information on the above programs and current offerings, contact John Newcomb, Center for Advanced Engineering Study, Room 9-221, MIT, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139, (617) 253-7400.

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 between 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 affiliates 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 which 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) 253-4149/4141.

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 the 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 Acting Director, Professor Roy E. Welsch, Room E40-129, MIT, Cambridge, Massachusetts 02139, (617) 253-8411.

Center for Health Effects of Fossil Fuels Utilization

The Center for Health Effects of Fossil Fuels Utilization was established through the collaborative efforts of combustion scientists and engineers, toxicologists, and analytical chemists in the Departments of Chemistry, Chemical Engineering, Applied Biological Sciences, and the MIT Energy Laboratory. The Center is funded by the National Institute of Environmental Health Sciences. Its associated research programs are funded by NIEHS, the US Department of Energy, and other governmental agencies. These research programs have provided challenging interdisciplinary problems for **graduate** and **undergraduate students.** Of particular importance is the emphasis on providing information sufficient to guide engineering design for combustion systems with lowered levels of biologically active emissions.

A primary mode of research involves analytical chemists working with combustion engineers to measure and identify the chemical components from experimental and practical combustion systems. Toxicologists first evaluate the biological activity of the raw exhausts 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 exhausts that are responsible for the biological activity. A second area of research is the study of the effects of gaseous and particulate combustion effluents on respiratory physiology. A third area is the development of means to measure the presence and biological effects of combustion-generated chemicals directly in humans. This research is now expanding because of recent advances in analytical chemistry and analytical genetics as applied to human blood samples. The goal is to discover which environmental chemicals (if any) actually do cause significant genetic changes in ordinary humans.

The findings of studies in all three areas have stimulated primary research efforts in understanding both the mechanisms of compound formation and the mechanisms of activity in inducing cancer and genetic change.

Center activities are coordinated by Professor William G. Thilly, Professor of Genetic Toxicology, 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 policymakers 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 computer-based information systems.

Research at CISR is pragmatic, problem-based, and application-driven. Research efforts are performed primarily in application areas of immediate interest to managers and policymakers. 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 the international dimension of contemporary policy questions, particularly those related to scientific and technological change. The Center has no formal teaching program of its own; most of its senior staff are faculty members of various MIT departments, and there are opportunities for **graduate students** to participate in the Center's research programs. The following are the areas of current research:

science and public policy
arms control and defense studies
US-Japan science and technology
energy policy
migration and development
technology and development
food and nutrition
US-China science and technology
international political problems and conflict
political and economic development

Further information may be obtained from the Director, Professor Eugene B. Skolnikoff, 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 reconstruction of the agricultural system developed by the ancient Maya. Interested students should contact Professor Heather Lechtman, Room 16-401, MIT, Cambridge, Massachusetts 02139, (617) 253-2172; Professor Arthur Steinberg, Room 20B-131C, 253-6956; or Dr. Frederick Wiseman, Room 20B-131B, 253-6973.

Center for Materials Science and Engineering

Major research programs currently supported by the Center emphasize interdisciplinary research in the following areas of thrust: 1) flow and fracture in high-temperature alloys; 2) defects in semiconductors; 3) phase transitions; 4) polymers; 5) innovations in high-strength 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, 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; a polymer facility; and scanning Auger, ESCA, and LEED 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, and the Sloan School of Management. The major research interests of the Center include the linkages between design quality and financial performance; the interaction between tax policy, monetary policy, and the availability of capital for development; models of the demand for different types of development; and research on new forms of public-private partnerships. The Center encourages interaction between members of the development industry and the academic community through seminars, colloquia, lectures, and a series of intensive summer courses. The Center is supported in part through corporate and personal 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, W31-300, 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 was established in 1985 within the School of Engineering to undertake research and teaching activities addressing the complex issues of technology and policy. The Center absorbs and expands upon the activities of the former Center for Policy Alternatives.

The new Center will be deeply involved in investigating how technology and industrial development can be advanced in a socially responsible manner, requiring an appropriate mix of public policy and private sector initiatives. More immediately, the Center seeks to build internal bridges that will link the many areas of MIT where technology and policy activities are under way. The collaborative work will involve faculty from engineering, science, law, management, and the social sciences. The Center expects to undertake long-term technology and policy projects with both national and international dimensions.

A Master of Science degree program in Technology and Policy was initiated in 1975 by the School of Engineering (see description under Technology and Policy in this chapter). This program will now become part of the teaching component of the new Center for Technology, Policy, and Industrial Development.

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; 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; finding ways of improving productivity in railroads, trucking, and transit; development of specific standards for highway maintenance and study of the performance of materials used in road construction; 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, and has recently completed a major international study on the future of the automobile, involving research teams not only at MIT but also at other universities in the United States, Japan, West Germany, France, Sweden, and the United Kingdom. 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 in cooperation with the Center, is designed to prepare students either for careers in transportation or for additional graduate work. The program is administered by the Center. Students with a variety of backgrounds such as engineering, social sciences, management, architecture, urban studies, and operations research are encouraged to 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 Applied Microeconomics — 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 are invited to propose programs of work in a second field leading to a second Master's degree. Some examples of second areas include engineering, operations research, city planning, 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, 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 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 has close ties with MIT faculty members which 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 which 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 daily association 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 which greatly broadens the students' educational experience.

CSDL, 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 (Ph.D.)

A doctoral program is offered jointly by the Departments of Economics and Urban Studies and Planning at MIT. The Joint Program recognizes the interrelationship between 1) the analytical aspects of policy questions and research opportunities in economics and 2) the institutional and policy orientation of urban studies. It has been recognized that both research and active intervention into urban problems benefit from the broadening of perspectives and institutional sophistication and the deepening of analytic penetration that a coordinated exposure to the two disciplines offers. This approach thus opens up a wider variety of career challenges than is available to specialists of either field alone. Students desiring to enter the Program must be admitted to **both** departments and then explicitly to the Joint Program. The Program is administered by a standing interdepartmental committee. Further information may be obtained from Professor Jerome Rothenberg, Room E52-355, MIT, Cambridge, Massachusetts 02139, (617) 253-2674, or from Professor William C. Wheaton, Room 10-403, 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 energy questions or illuminate energy issues. Energy Laboratory research projects this year involve over 100 research staff, 80 faculty, and over 200 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 structure and regulation of the energy industries and markets, and the interaction between energy markets and the macroeconomy. Current research focuses on the structure and regulation of the US electric utility and natural gas industries; income distribution, productivity, and economic growth effects of changing energy prices; and energy use and conservation. New research directions include economic/financial studies of primary resource firms and of large-scale energy technology investments.

The Center for Energy Policy Research focuses on policy research and analysis and on making results available and useful to policy-makers. With support from its Associates, a wide range of US and international corporate and noncorporate interest groups, the Center holds conferences and seminars to bring together key government and private organizations to work on energy-related policy issues. The work of the Center is done by professional staff members from the Energy Laboratory and faculty and students from several MIT departments (particularly the Sloan School of Management and the Department of Economics), and specialists from the Center's Associates.

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, pyrolysis, slurry rheology, gas desulfurization, and refracting corrosion.

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.

The Advanced Energy Materials program examines new and emerging technologies in such areas as electrodes and electrolytes for high-density batteries and fuel cells, synthesis of ceramic powders using laser heat sources, rapid solidification of molten ceramics, solar heating/cooling, amorphous photovoltaics, and broad-band antireflective coatings.

Research in the Environmental program seeks to identify and reduce the environmental impacts of 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 16 utilities; 10 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 fuel resources; and 3) to develop and communicate information that will contribute to public understanding 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. Current projects include studies of the transfer and accumulation of moisture in structures retrofitted with insulation, heat loss from building foundations, and the insulating value 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, 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 towards 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 buildings, 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 subjects 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.

Environmental Studies

Environmental studies for **undergraduate** and **graduate students** are available through a variety of departmental and interdepartmental subjects and laboratories. Both the technical and the policy aspects of environmental studies are explored in subjects offered by the Departments of Civil Engineering, Mechanical Engineering, Ocean Engineering, Chemical Engineering, Earth, Atmospheric, and Planetary Sciences, Urban Studies and Planning, and the Program in Science, Technology, and Society. The areas of environmental studies available at MIT include air and water quality; pollution control; water, ocean, and energy resource management; public policy and planning for the environment; and the impacts of technology on the environment. In addition, many departments offer other educational and research opportunities in specific areas of the environment closely related to their own disciplines.

Undergraduates whose interests span more than one discipline may arrange a coordinated program of interdisciplinary environmental study by entering one of the unspecified degree programs sponsored by many of the departments. Undergraduate students who have a disciplinary commitment but desire a coherent minor program of environmental study may do so through use of the unrestricted electives available to them.

Graduate students may pursue environmental studies in various ways. Through its several departments, the School of Engineering sponsors the degree of Environmental Engineer. The Energy Laboratory supports research on environmental issues which cross academic departments and Schools. The Program in Technology and Policy promotes careers in the development and implementation of policies for the productive use and control of technology. Major research with opportunities for graduate study in environmental policy and impact assessment is undertaken by the Laboratory of Architecture and Planning and the School of Architecture and Planning.

There also are opportunities in the environmental area under the auspices of the joint programs of MIT and the Woods Hole Oceanographic Institution. (The above programs are described in this chapter and in Chapter VII.) Graduate students may also arrange special programs with the help of their advisors in aspects of the environment which are closely related to their disciplinary interests, and they may pursue interdepartmental programs leading to advanced degrees under the auspices of the Dean of the Graduate School. See environmental listings under individual departments for more specific information.

Information concerning environmental education and research activities at MIT is centered in the Office of the Provost, which works with faculty members and appropriate centers and laboratories. Further information, lists of departmental advisors, and subjects offered on environmental issues for both undergraduate and graduate students are available through the Office of the Provost, Room 3-208, MIT, Cambridge, Massachusetts 02139.

ESG (Experimental Study Group)

ESG is open to **freshmen** and **sophomores** interested in participating in a small, informal academic program which offers credit primarily in core subjects through tutorials, seminars, and independent study. 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 Chapter VII in this catalogue.

Humanistic Studies Combined with Engineering or Science (S.B. Degree Programs in Courses XXI, XXI-E, XXI-S)

MIT has developed programs for **undergraduate students** who have an active interest in the relationship between humanistic and scientific/technical knowledge. The first (XXI) is a *double-degree* arrangement leading to two

S.B. degrees, one centered in the curricula of the Department of Humanities and the Program in Science, Technology, and Society (STS); the other in one of the degree programs in the School of Science or the School of Engineering. The second (XXI-E, XXI-S) is a *joint-degree* major which brings together components of humanities/STS and engineering/science within the dimensions of a single S.B. program.

Both of these plans require substantial knowledge in each of the two chosen areas, and both are grounded in a rigorous system of seminars and other subjects expressly designed to relate scientific learning and technological choice to social and cultural issues.

More detailed descriptions of these programs, including outlined degree requirements, are included in the Department of Humanities and STS descriptions in Chapter VII of this catalogue.

Further information may be obtained from Professor Travis Merritt of the Course XXI Office, Room 14N-407, MIT, Cambridge, Massachusetts 02139, (617) 253-4447; or Professor Peter Buck of the Program in Science, Technology, and Society, Room E51-128, 253-4043.

Integrated Studies Program

The Integrated Studies Program offers a group of about 50 **freshmen** an opportunity to fulfill their first-year General Institute Requirements as a coordinated educational experience. While physics, chemistry, mathematics, and the humanities are taught as separate academic disciplines, care is taken to bring out their interrelationships and interactions at seminars and through synthesis-oriented assignments. 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), jointly established by the Department of Applied Biological Sciences and the Center for International Studies, 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. In the 1970s, highlights of the Laboratory's work were MACSYMA, a 2-Megabyte program with knowledge in symbolic mathematics; the dataflow concept, which is important for harnessing thousands of processors to work on a common task; the use of computers in clinical decision making; and public cryptography algorithms aimed at insuring privacy in distributed/networked computer systems. 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; and 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 UROP. Facilities are provided for thesis research and special projects to both graduate and undergraduate students.

Further information may be obtained by contacting John J. Hynes, Room NE43-101, MIT, Cambridge, Massachusetts 02139, (617) 253-2006.

Laboratory for Electromagnetic and Electronic Systems

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 17 faculty and 10 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, insulation research, quantitative physiology, cell biology, and economics. Support from other Institute and area laboratories frequently provides opportunities at LEES for interdisciplinary research.

Research in power electronics centers on the MIT-developed Parity Simulator, which, through the MIT/Industry Power Electronics Collegium, is a focus for industry research in circuit design, analysis of power electronic devices, and systems analyses. In cooperation with the VLSI Laboratory, several current projects exploit VLSI technologies, while others contribute to the advanced control of electrical machines and the modeling of power systems. Other activities relating to automatic control, with the Laboratory for Information and Decision Systems, center on various forms of machines that integrate electromechanics with digital and power electronics. The resulting machines have applications ranging from washing machines to robotics. LEES members are currently completing a 10MVA superconducting alternator with the Cryogenics Laboratory, which is a major step forward in the development of large-scale generation equipment, as well as a testbed 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 high-voltage research at LEES. With the objective of understanding microdischarges 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 Materials Science Center and the Energy Laboratory, microdischarges, electromechanically induced vibrations, micro-dielectrospectrometry, and chemical sensing are combined 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 electrostatic paint spraying and the development of AC electrostatic precipitators for coping with highly insulated combustion products that result from burning western coals.

With the Children's Hospital, work is being carried out on the continuum electromechanics of 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. The study of the effects of environmental electric and magnetic fields on biological systems, especially in electric power systems, is the focus of research in this area. The electron beam and other high-voltage radiation facilities have a long tradition of medical applications. These facilities continue to be a resource in promoting physical and chemical processes.

Another interdisciplinary activity within LEES is concerned with energy 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) 253-4631.

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.

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 Office of the Director, Professor S. K. Mitter, Room 35-304, MIT, Cambridge, Massachusetts 02139, (617) 253-2160, or the Associate Director, Professor R. G. Gallager, Room 35-206, 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 increase based on a systematic understanding of the complex interactions among the many areas of manufacturing including design, processing, assembly, inspection, and quality control. The impact of the new manufacturing technology on society is also addressed.

The Laboratory draws upon faculty and staff in the Departments of Mechanical Engineering, Electrical Engineering and Computer Science, Chemical 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, intelligent manufacturing systems, and manufacturing science.

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 **undergraduate** 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

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, the Center for Theoretical Physics, and a computer facility available to 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. Also, several small groups within the Laboratory are engaged in the application of nuclear and particle physics instrumentation to medical and biological problems.

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 Electron 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 eligible researchers in the New England area and nationwide.

The Laboratory supports a broad program of research in electromagnetic interactions with nuclei. Facilities are available for high precision-high resolution electron scattering and photoreactions including pion production. The maximum electron energy available is 780 MeV; a further increase to about 1 GeV is anticipated at the end of 1986. A polarized electron source is under development which will make possible studies of parity violation in electron scattering and spin effects in nuclear reactions. Plans are being developed to increase the duty factor to nearly 100 percent.

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 6-308A, 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; and innovative approaches to communicating research findings to the public. The LAP's primary area of development is building technology.

The LAP provides a range of continuing education 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 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, the legal profession, or our legal structure and processes as a part of a general education may do so through a wide range of undergraduate or graduate subjects, research projects, seminars, and fieldwork opportunities. 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 some areas, work is undertaken collaboratively with law schools in the area. In addition to several lawyers on the teaching staffs of five different departments, there are lawyers on the administrative staff with experience in a variety of fields which they are willing to share with students.

In recent years, a substantial number of 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. Field research and work opportunities offer other means for testing an interest in the law.

The Office of Career Services and Preprofessional Advising, Room 12-170, (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.

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 Dr. Melvin A. Herlin, Assistant to the Director, LIN A-163, (617) 863-5500, extension 7024, or Institute extension 181-7024.

Management of Technology Program (S.M.)

The Management of Technology Program is a 12-month master's degree program, beginning only in June of each year, for technical professionals with a minimum of five years work experience. Offered jointly by the School of Engineering and the Sloan School of Management, the program focuses on management principles for individuals whose careers require increasing managerial responsibility on the technical side of the organization.

The rigorous, 12-month curriculum, developed and taught by faculty from both Schools, leads to a Master of Science in the Management of Technology and covers three elements:
1) underlying core subjects in management principles 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 1. Requirements for admission include five years of technical work experience and an undergraduate technical degree. In addition, 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 provides an interdisciplinary focus on the processing and performance of materials. The Center stresses the control of the internal structure of materials during processing, from the macroscopic to the atomic level, to control materials performance. The Center promotes processing techniques that are economical, energy-efficient, and socially acceptable.

Dedicated to the development and expansion of the fundamental scientific and technological base of materials processing, the Center pursues a three-pronged approach with interdisciplinary research, education, and advisory programs.

To solve critical, basic processing problems, the Center coordinates faculty expertise and facilities from a number of departments, principally Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemical Engineering. Center research concentrates on all engineering materials, including metallic, ceramic, polymeric, and electronic materials.

Center educational programs strive to attract outstanding students to the study of materials processing. The Center offers special summer scholarships to **undergraduate** students. It awards fellowship appointments to outstanding first-year **graduate students** and supports others through research programs funded by grants and contracts through the Center. The Center also conducts continuing education programs to introduce professional engineers and scientists to recent technological information.

The Center has strong links with both industry and government. Through the Industry Collegium, it provides a forum for industrial representatives to discuss their needs and problems with researchers in the university. Through workshops and symposia, the Center distributes knowledge and information on innovative and recent scientific and technological developments. It also sponsors the appointments of industry and government personnel as visiting faculty, adjunct faculty, and postdoctoral researchers.

For further information, contact Professor R. M. Latanision, Director, at (617) 253-4697, Room 8-202, or Dr. G. B. Kenney, Assistant Director, 253-3244, Room 12-007, MIT, Cambridge, Massachusetts 02139.

Media Arts and Sciences

Media Arts and Sciences is an academic program for **graduate students,** and is affiliated with the interdisciplinary laboratory known as the Media Lab. The program comprises 10 previously separate groups that now reside in the Wiesner Building, newly constructed for this purpose. The Ph.D. in Media Arts and Sciences includes concentrations in epistemology and learning, electronic media, and computer music. A description of the M.S. program can be found under the School of Architecture and Planning in Chapter VII.

The faculty affiliated with this program believe there is a unique discipline to be found at the intersection of the communications and cognitive sciences; one that is expressed by the invention and creative use of modern electronic media. Primary areas of application include education, medicine, electronic publishing, entertainment, and the arts.

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 in 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 Art and Architecture. Further information is available from Professor Nazli Choucri, Department of Political Science, Room E53-493, MIT, Cambridge, Massachusetts, (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). Students' emphases 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 the education of 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** and **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 training in the Japanese language through credit or noncredit study. Students must also successfully complete additional courses in Japanese science, society, economics, politics, and history. The Program trains and supervises the placement of eight to ten 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 E53-447, MIT, Cambridge, Massachusetts 02139, (617) 253-3142 or 2449.

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 Applied Biological Sciences 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 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 MITR-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 which 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 thesis. **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 education 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 Physics. The Center is composed of approximately 20 affiliated faculty and 40 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 Center 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, Markov Models and Their Applications (6.262), Introduction to Stochastic Processes (15.073J/18.445J), Statistics for Model Building (15.076J/18.457J), Network Optimization (15.082), Combinatorial Optimization (15.083), and Nonlinear Programming (15.084J/6.252J). Doctoral degree candidates must qualify for continuation in the program by passing Qualifying and General Examinations which are taken in the second year of a typically four-year program. Course work 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 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 Richard C. Larson and Jeremy F. Shapiro.

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 urgent and 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 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 Mirror Confinement Systems Division is developing an increased understanding of basic tandem mirror physics with emphasis on stability properties, thermal barrier formation, and RF heating. The subprogram areas include the TARA tandem mirror and CONSTANCE mirror experiments.

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 tokamak experiment.

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 currently holds the world record in obtaining the highest product of plasma density times confinement time, and is 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** 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 C. Davidson, Room NW16-202, Cambridge, Massachusetts 02139, (617) 253-8102.

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.

A **graduate student** enrolled in any of these departments may construct from among various subject offerings and research activities an academic program and thesis research which he or she wishes to pursue. 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.

In addition to the departments listed above, research in power systems 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.

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 will 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, will provide 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 will take 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 Robert E. Cohen, Director, Program in Polymer Science and Technology, Room E19-356, MIT, Cambridge, Massachusetts 02139, (617) 253-3115.

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, auditory psychophysics, and auditory physiology.

Additional research foci include fundamental studies in atomic and molecular 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 100 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.

Research Program on Communications Policy

Rapid technological change and the critical importance of communications to society have combined to generate intense concern with policymaking in this area. This interdisciplinary field which draws on engineering, economics, policy analysis, legal studies, management, political science, and the sociology of communications effects is an area of active study and research at MIT.

There is a graduate degree program in Communications Technology and Policy within the Department of Political Science. Some **graduate students** have developed their own interdisciplinary course of study in communications through the Program in Technology and Policy, or through other departments including Electrical Engineering and Computer Science, Economics, the Sloan School of Management, and the School of Architecture and Planning. **Undergraduates** may wish to explore the UROP projects available in communications research and review the course listings of the Film and Media Concentration. Further information on the Concentration is available from the Literature Faculty Office, Room 14N-305, MIT, Cambridge, Massachusetts 02139, (617) 253-3581.

Program faculty are available to advise interested graduate students in the design of their course of study, to put them in touch with ongoing research activity at the Institute, and to help with professional placement. Recent dissertations and faculty research associated with the program have included studies of the politics of spectrum allocation, policymaking in the French television system, satellite communications, interactive media and video games, high-definition television, the social impact of the telephone, telecommunications facilities in rural Egypt, and Federal regulation of cable television.

The Program publishes an interdisciplinary course list, organizes seminars on special topics in cooperation with the Communications Forum, and publishes an annual report describing recent and upcoming research and teaching activities concerned with communications policy. The Program is housed in the Center for Technology, Policy, and Industrial Development.

For further information, contact Professor W. Russell Neuman, Director, Room E53-367, 253-6630.

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 Carl Kaysen, Room E51-110, MIT, Cambridge, Massachusetts 02139, (617) 253-4062.

Sea Grant College Program

Dedicated to advancing the vital roles of engineering and science in the development of ocean and coastal resources, the Sea Grant Program funds and coordinates multidisciplinary research projects, educational opportunities, and advisory services. Following the lead of the National Sea Grant Program, created by Congress in 1966, MIT recognizes the need to respond to opportunities in the marine field, and to solve current technological, economic, social, and political problems caused by our increasing and conflicting uses of the seas. The designation in 1976 of MIT as the nation's twelfth Sea Grant College, the first private institution to achieve this distinction, strengthened the Institute's commitment to furthering wise use and development of the ocean's resources.

The Sea Grant research program reflects the conviction that the Institute's expertise and facilities can help solve critical problems in 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 Applied Biological Sciences, Civil Engineering, Ocean Engineering, and Mechanical 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 utilization and coastal zone development. Each year, an interdisciplinary design subject provides graduate and undergraduate students with the chance to apply classroom knowledge to "real-world" situations. 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, business, and organizations to transfer comprehensive information to the public on the many facets of resource development in the oceans and coastal zones.

More information on Sea Grant Program projects and services may be obtained from 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, Applied Biological Sciences, 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 organo-metallic 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.

Within the Laboratory is the Laser Research Center, supported by grants from the National Science Foundation for physical sciences research and from the National Institutes of Health for biomedical research. This Center makes available to researchers from various university and industrial research institutions one of the most extensive collections of lasers in the US for spectroscopic research. Facilities include a turnable Excimer Laser, two Nd:YAG Lasers, four Pulsed Dye Lasers, several CW

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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 (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 have as a prerequisite one previous philosophy subject	
Required Subjects:	60
24.200 Socrates and Plato, 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	
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.

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:	69-72
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, 9	
24.901J Language and Its Structure, 9; 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:	48
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 Socrates and Plato, 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:	69
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, 9	
24.901J Language and Its Structure, 9; 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	105-120
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
24.956	Introduction to Linguistics IV: Universal 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
24.972	Language and Computation
24.973	Topics in Logic and Semantics
24.982	Linguistic Change
24.992	Survey of General Linguistics I

Before students may begin their doctoral research they are required to pass a comprehensive General Examination which 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 which 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

Professors

Hayward Rose Alker, Jr., Ph.D.
Professor of Political Science
(On leave)

Suzanne Berger, Ph.D.
Ford International Professor of Political Science

Lincoln Palmer Bloomfield, Ph.D.
Professor of Political Science

Walter Dean Burnham, Ph.D., Lit.D.
Ruth and Arthur Sloan Professor of Political Science
(On leave, fall)

Edwin Diamond, M.A.
Professor of Political Science
(Visiting)

Nazli Choucri Field, Ph.D.
Professor of Political Science

William Edgar Griffith, Ph.D.
Ford International Professor of Political Science
(On leave, fall)

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

George William Rathjens, Ph.D.
Professor of Political Science

Robert Irwin Rotberg, D.Phil.
Professor of History and Political Science

Harvey Morton Sapolsky, Ph.D.
Professor of Public Policy and Organization

Eugene Bertram Skolnikoff, Ph.D.
Professor of Political Science
Director, Center for International Studies

Peter Hopkinson Smith, Ph.D.
Professor of History and Political Science

Myron Weiner, Ph.D.
Ford Professor of Political Science

Associate Professors

Joshua Cohen, Ph.D.
Associate Professor of Political Science and Philosophy

Stephen Michael Meyer, Ph.D.
Associate Professor of Political Science

William Russell Neuman, Ph.D.
Associate Professor of Political Science

Barry R. Posen, Ph.D.
Associate Professor of Political Science
(On leave)

Charles Frederic Sabel, Ph.D.
Associate Professor of Social Science
(On leave, fall)

Richard Joel Samuels, Ph.D.
Associate Professor of Political Science

Brian Henry Smith, Ph.D.
Associate Professor of Political Science

Assistant Professors

Daniel Metlay, Ph.D.
Assistant Professor of Political Science

Charles Stewart III, Ph.D.
Assistant Professor of Political Science

Richard M. Valelly, Ph.D.
Assistant Professor of Political Science

Senior Lecturer

Louis Menand III, Ph.D.

Lecturers

Charles M. Jonscher, Ph.D.
Peter H. Lemieux, Ph.D.
Steven E. Miller, B.A.
R. Michael Tyler, M.A.

Visiting Lecturer

Richard Greene, Ph.D.

Administrative Officer

Anne M. Grazewski

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 which 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 which incorporates political sociology, political psychology, political demography, and economic and political development.

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 which 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.

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:	**18**
17.913 Pre-thesis Reading Seminar (9 units)	
17.ThU Undergraduate Political Science Thesis (at least 9 units)	
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**

*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
1.00 Introduction to Computers and Engineering Problem Solving and 14.30 Introduction to Statistical Method in Economics are suggested.

Graduate Study

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 and Public Policy

This program is intended both for mid-career professionals and for recent college graduates interested in career-oriented training for positions in government, the media, business, banking, research institutes, and nonprofit institutions. The program may also be suitable for students who think of working toward a Ph.D.

Four public policy fields are offered within this program: 1) Defense and Arms Control; 2) Science, Technology, and Public Policy; 3) Communications Policy; 4) International Development. Each specialty is structured so that each student takes one or more subjects on the policy process, methods of policy analysis, and substantive policy issues.

Students from a wide variety of disciplinary backgrounds and professional experience are welcomed. For mid-career professionals, at least eight courses are required for the S.M. degree, plus a thesis. Students without professional experience are ordinarily required to take 12 courses, plus a thesis. Students are expected to enter with or acquire an intermediate-level competence in both micro- and macroeconomics. The department places great importance on tailoring programs to meet the particular competences and needs of students. Interested students are encouraged to write to us about their interests or personally visit the department. The general requirements for the S.M. are described in Chapter IV.

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. Students wishing to concentrate in any of the specialized fields offered in the S.M. program in Political Science and Public Policy (described above) should apply to that program. Students interested in other fields offered by the Department should apply for the S.M. in Political Science. 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 competences. 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 may be acceptable. A program in urban politics and planning is offered jointly with the Department of Urban Studies and Planning, and a program in international planning is offered with the International Food and Nutrition Program (both described in Chapter VI). There also are a variety of joint MIT-Harvard University teaching programs in subjects such as Analysis of Complex Systems, West European Studies, and political demography.

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 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, the Joint Center for Urban Studies, and the Center for Policy Alternatives (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 Department Head, Professor Donald L. M. Blackmer, E53-470, MIT, Cambridge, Massachusetts 02139, (617) 253-5262.

Program in Science, Technology, and Society

(STS)

Carl Kaysen, Ph.D.
David W. Skinner Professor of Political Economy
Director, fall term
(On leave, spring)

Kenneth Keniston, Ph.D.
Andrew W. Mellon Professor of Human Development
Director, spring term

Peter Buck, Ph.D.
Associate Professor of the Social Study of Science
Academic Officer

Professors

Donald Laurence Morton Blackmer, Ph.D.
Professor of Political Science
Head, Department of Political Science

Loren R. Graham, Ph.D.
Professor of the History of Science

Gerald Holton, Ph.D.
Professor of the History of Science
(Visiting)

Evelyn Fox Keller, Ph.D.
Professor of the Sociology of Science
(Visiting)

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

Leo Marx, Ph.D.
William R. Kenan Professor of American Cultural History

Robert Swain Morison, M.D., D.Sc.
Professor of Science and Society
(Visiting)

Michael Joseph Piore, Ph.D.
Mitsui Professor in Problems of Contemporary Technology
Professor of Economics

Walter Alter Rosenblith, Ing. Rad.
Institute Professor, Emeritus
Provost, Emeritus

Merritt Roe Smith, Ph.D.
Professor of the History of Technology

Leon Trilling, Ph.D.
Professor of Aeronautics and Astronautics

Charles Weiner, Ph.D.
Professor of the History of Science and Technology
(On leave, fall)

Jerome Bert Wiesner, Ph.D.
Institute Professor, Emeritus
President, Emeritus

Associate Professors

Louis Lawrence Bucciarelli, Ph.D.
Associate Professor of Engineering and Technology Studies

Emma Rothschild, M.A.
Associate Professor of Technology, Society, and Rhetoric
(On leave)

Charles Frederic Sabel, Ph.D.
Associate Professor of Social Science
(On leave, fall)

Sharon Traweek, Ph.D.
Associate Professor of Anthropology and Science, Technology, and Society
(On leave)

Sherry Roxanne Turkle, Ph.D.
Associate Professor of Sociology

Principal Research Associate

Victor McElheny, B.A.

Principal Research Scientist

Kosta Tsipis, Ph.D.

Professor Emeritus

Elting Elmore Morison, A.M.
Elizabeth and James Killian Class of 1926 Professor, 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.

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 130J/21.901J and STS 131J/21.902J) 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 132J/21.903J), 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 which 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 three 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 130J/21.901J and STS 131J/21.902J) — 18 units	
Project Seminar (STS 132J/21.903J) — 9 units	
Planned Electives:	**81-108**
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 one must be in each of 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	
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 which provide a focus for interdisciplinary work. Central to this core is a yearlong reading seminar (STS 130J/21.901J and STS 131J/21.902J), 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 130J/21.901J and STS 131J/21.902J) — 18 units	
Project Seminar (STS 132J/21.903J) — 9 units	
Planned Electives:	at least 81
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 one must be in each of 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	
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.

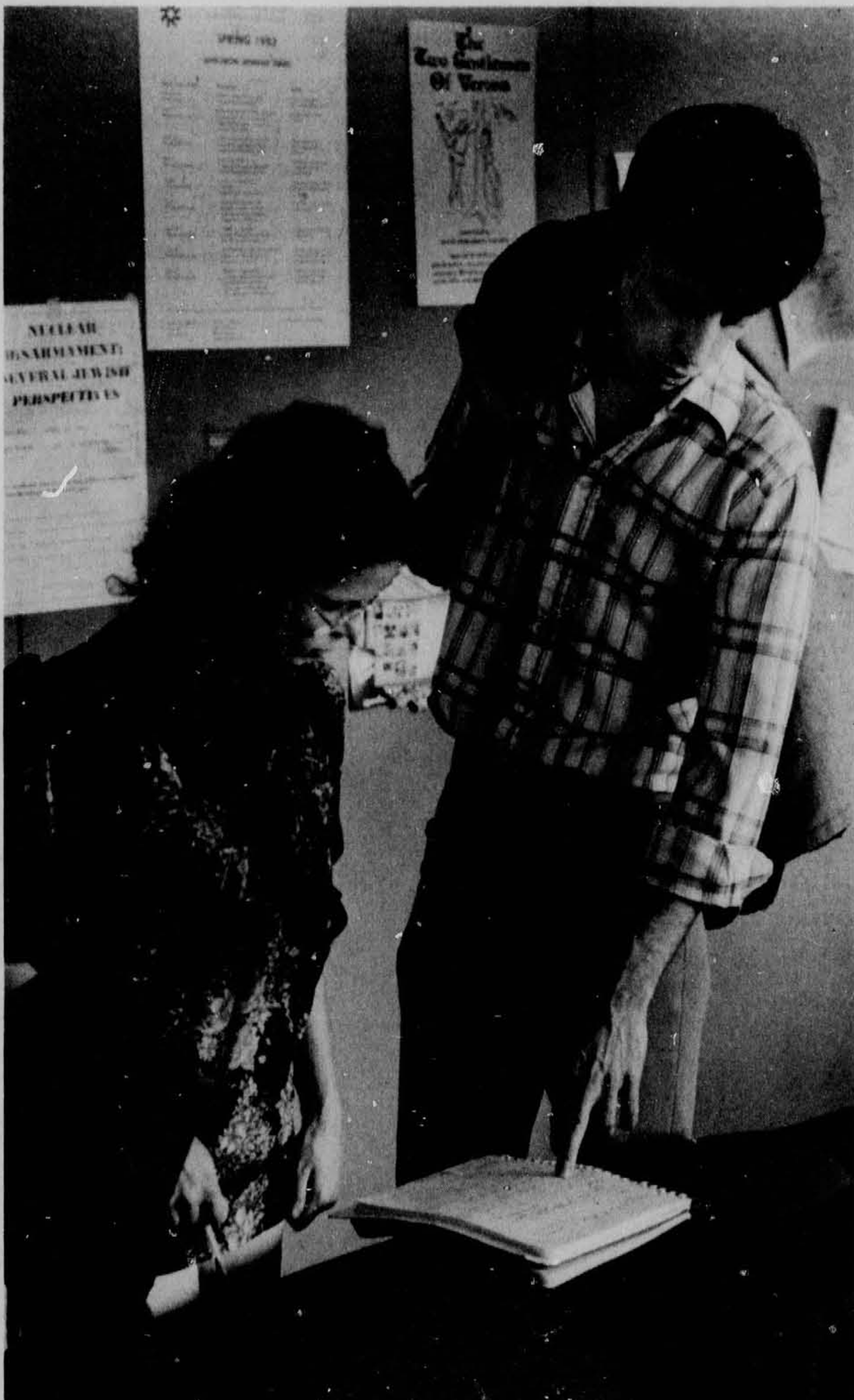
Inquiries

Additional information on the Program in Science, Technology, and Society may be obtained from Professor Peter Buck, Room E51-128C, MIT, Cambridge, Massachusetts 02139, (617) 253-4043.

For detailed descriptions of subjects in Science, Technology, and Society, see STS 101-636 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.

In its efforts, the Sloan 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. 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, of health services, of education, and of public and urban affairs.

Sloan School of Management

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.

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Dean

Alvin J. Silk, Ph.D.
Erwin H. Schell Professor
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Deputy Dean

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Psychology and Management
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(Visiting)

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Professor of Management Science
(On leave, spring)

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Alfred P. Sloan Professor of
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(Visiting)

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and Management

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Professor of Management, Emeritus

Eli Shapiro, Ph.D.
Alfred P. Sloan Professor of Management, Emeritus

Phyllis Ann Wallace, Ph.D.
Professor of Management, Emeritus

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 and communications 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 three to five 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. Students who wish broader general education are encouraged to take additional subjects in the humanities, arts, and social sciences, beyond the Institute Requirements. 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 E52-119, MIT, Cambridge, Massachusetts 02139, (617) 253-2931.

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	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: 78

6.041	Probabilistic 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	Financial and Cost Accounting, 9
18.06	Linear Algebra, 12; 18.02

Restricted Electives: 54 to 81

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 or 15.560

Two of the following five subjects: [2]

15.351	Managing Technology and Innovations, 9; 15.301, 15.501
15.412	Financial Management II, 12; 15.501
15.664	Management of Human Resources, 9; 15.301
15.761	Operations Management, 9; 15.053**, 6.041**
15.812	Marketing Management, 9; 6.041**

Planned Electives:

Four specified subjects in one of the following options: Information Systems, Operations Research, Marketing Research, Behavioral Science, 27 to 45[3]

Units in Departmental Program that also satisfy the General Institute Requirements (36)

Unrestricted Electives 57-84

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.

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	Probabilistic 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	Financial and Cost Accounting, 9
18.06	Linear Algebra, 12; 18.02

Restricted Electives: 54 to 81

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 or 15.560

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15.351	Managing Technology and Innovations, 9; 15.301, 15.501
15.412	Financial Management II, 12; 15.501
15.664	Management of Human Resources, 9; 15.301
15.761	Operations Management, 9; 15.053**, 6.041**
15.812	Marketing Management, 9; 6.041**

Planned Electives:

Four specified subjects in one of the following options: Information Systems, Operations Research, Marketing Research, Behavioral Science, 27 to 45[3]

Unrestricted Electives 96 to 69

Total Units Required for the S.B. Degree 360

**Alternate prerequisites are also listed in the subject description.

1
14.01 and 14.02 may be substituted for 15.001.
2
Both 15.351 and 15.664 cannot satisfy the Restrictive 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 (E52-119).

Graduate Study

The Sloan School of Management provides 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 applicants 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 master's student's time, 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, Planning, and Control; 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 into 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.

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 three to 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, so as to avoid unnecessary delays in 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, Planning, and Control
Applied Economics
Finance
Health Care Management
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 late May of the second 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 which, 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 in 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 non-degree 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.

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

Applied Biological Sciences (Course 20)
Biology (Course 7)
Chemistry (Course 5)
Earth, Atmospheric, and Planetary Sciences (Course 12)
Mathematics (Course 18)
Physics (Course 8)

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 six 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 from cell biology, microbiology, biochemistry, and biophysics, to food science and technology, 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 which are closely related to the Department of Biology. The Whitehead Institute for Biomedical Research is affiliated with MIT, and its faculty members hold faculty appointments in the Department of Biology. The Clinical Research Center is an interdepartmental laboratory which is closely related to the Department of Applied Biological Sciences. 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

Department of Applied Biological Sciences

Gerald Norman Wogan, Ph.D.
Professor of Toxicology
Underwood-Prescott Professor
Head of the Department

Professors

John Francis Burke, M.D.
Professor of Experimental Surgery
(Visiting)

Charles Leland Cooney, Ph.D.
Professor of Chemical and Biochemical Engineering

Arnold Lester Demain, Ph.D.
Professor of Industrial Microbiology

Samuel Abraham Goldblith, Ph.D.
Professor of Food Science
Vice President, Resource Development, Emeritus

Marcus Karel, Ph.D.
Professor of Food Engineering

Robert Samuel Langer, Sc.D.
Professor of Biochemical Engineering

Robert Spencer Lees, M.D.
Professor of Cardiovascular Disease

Richard Alan North, M.D., Ph.D.
Professor of Neuropharmacology

Nevin Stewart Scrimshaw, Ph.D., M.D., M.P.H.
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Associate Professors

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Michael Anthony Marletta, Ph.D.
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Cho Kyun Rha, Sc.D.
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Assistant Professors

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Assistant Professor of Applied Biological Sciences

Renee Ann Fitts, Ph.D.
Assistant Professor of Applied Biological Sciences
Henry L. Doherty Professor in Ocean Utilization

Marsha Rich Rosner, Sc.D.
Assistant Professor of Toxicology

Adjunct Professor

Hamish Nisbet Munro, M.B., D.Sc.
Adjunct Professor of Physiological Chemistry

Senior Lecturers

Charles S. Davidson, M.D.
Edward S. Josephson, Ph.D.
Charles J. Kensler, Ph.D.

Lecturers

Sanford Arthur Miller, Ph.D.
William Medden Rand, Ph.D.
Christophe Riboud, Ph.D.
Israel A. Saguy, Ph.D. (Visiting)
Frederick Schoen, Ph.D., M.D.
Bernard Yon, Ph.D.
Steven Zeisel, M.D., Ph.D.

Administrative Officer

Lydia S. Snover, M.B.A.

Senior Research Scientist

Mary O. Amdur, Ph.D.

Research Scientists

Tim Ahern, Ph.D.
Andrew G. Braun, Ph.D.
William Fisher Busby, Ph.D.
Lung Chi Chun, Ph.D.
William Dietz, M.D., Ph.D.
Paul Skipper, Ph.D.
John Sherman Wishnok, Ph.D.
John Williams, Ph.D.
Judith Hirschhorn Wurtman, Ph.D.

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Kang Choi, Ph.D.
Maria Constantini, Ph.D.
Charles Couet, M.D.
Eugenia Dogliotti, Ph.D.
Abraham Domb, Ph.D.
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Michael Lacey, Ph.D.
Elizabeth Leibold, Ph.D.
Wolfgang Liebel, Ph.D.
Alexey Margolin, Ph.D.
Misao Miwa, Ph.D.
Barbara Muller, Ph.D.
Claudy Mullon, D.Sc.
Guy Page, Ph.D.
Oliver Patrick Peoples, Ph.D.
Jack Rogers, Ph.D.
Barbara Sanderson, Ph.D.
Norman Shepphard, Ph.D.
Michael Wildschutte, Ph.D.

Professors Emeriti

Paul Medford Newberne, D.V.M., Ph.D.
Professor of Nutritional Pathology, Emeritus

John B. Stanbury, M.D.
Professor of Experimental Medicine, Emeritus

Department of Applied Biological Sciences

(Course 20)

Undergraduate Study

Research in Applied Biological Sciences requires persons with multidisciplinary training in mathematics, physics, chemistry, and modern biology. Because many MIT undergraduates are well prepared in the fundamentals of science and engineering, faculty members are able to offer them responsible positions in the Department's major research efforts. As part of their involvement, students train in the experimental method (not generally available in single-term laboratory courses) and develop a deeper understanding of strategy and tactics in modern research and research management. Students graduating from Course VII-B go on to medical or graduate schools, and then to careers in medicine, academic and industrial research, or government service.

In fact, undergraduate research training in direct association with the faculty, whether in theses, special projects, or UROP, is the hallmark of the Department's contribution and commitment to undergraduate education at MIT.

The research programs of the Department have three broad targets: 1) Understanding the relationship between exposure to chemicals and human disease; 2) Understanding the organization and behavior of neural and metabolic regulatory systems in humans and experimental animals; and 3) Engineering microbes, enzymes, and materials for use in developing biologically active products or medically useful devices.

Eight faculty share responsibility for education in toxicology and participate in a series of interrelated research programs with the common aim of identifying which of the myriad chemicals to which humans are exposed daily have significant effects on human health. The program has an emphasis on carcinogenesis and genetic disease. Research projects focus on cell surface phenomena and control of cell division, as well as the processes of mutagenesis.

Six faculty are engaged in studies of neural and/or metabolic control in experimental mammals or humans. Special emphasis is given to the role of dietary factors in health and disease.

Eight faculty have strong research programs in biotechnology — devising improved means of drug delivery; applying fundamental concepts of chemical engineering from bacterial to human cell production systems; and using modern techniques in organic chemistry and molecular biology to create more useful biological products such as immobilized enzymes, diagnostic reagents, and viral vaccines.

Undergraduates enrolled in Course VII-B, Applied Biology curriculum, and students in other Departments with a strong interest in obtaining significant research experience in biotechnology and biochemical engineering, toxicology, pharmacology, or neural and metabolic regulation are encouraged to visit the Department's Student Office (Room 16-330) for guidance or to contact faculty directly for advice.

Curriculum in Applied Biology — Course VII-B

The curriculum in Applied Biology emphasizes fundamental subjects in the physical and biological sciences as preparation for careers in the biotechnology and pharmaceutical industries, education, medicine, or in the continuing national effort toward providing a healthful environment. Our faculty shares responsibility for teaching biology core subjects, such as genetics and physiology. Special emphasis is placed on research experience in faculty laboratories. The required laboratory, 20.002, is specifically designed to prepare MIT undergraduates to enter biological research laboratories during their sophomore year. While requiring 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 offered in this Department (such as Human Physiology, Pharmacology and Toxicology, Mechanisms of Pathogenesis, Control of Cellular Metabolism, General Toxicology, Physical Chemistry of Biomaterials, and Biotechnology) and for additional study in basic subjects offered in other departments. Serious students should consider several subjects beyond the minimum requirements, such as Differential Equations 18.03, Waves and Optics 8.03, a third term of Organic Chemistry (5.43), computer programming, and additional topics in physical chemistry.

1
Students who take 5.11 to satisfy the General Institute Requirement in Chemistry must take 12 additional units of Unrestricted Electives.

2
A graduate subject from the following list may be substituted for one of these subjects: 20.112, 20.511J, 20.611, 20.734, 20.801.

3
Completion of this requirement involves a written report for 20.011/20.012, or a thesis for 20.ThU.

Bachelor of Science in Life Sciences Course VII-B Applied Biology Curriculum

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 5.60 and 7.05 in the Departmental Program]	3
Laboratory Requirement [can be satisfied by 20.002 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:		123
5.11	Principles of Chemical Science,[1] 12	
5.12	Organic Chemistry I, 12; 5.11	
5.13	Organic Chemistry II, 12	
5.60	Chemical Thermodynamics, 12; *18.02*	
7.01	General Biology, 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; 18.001 or 18.01 or 18.011 or 18.012	
20.002	Laboratory in Applied Biology, 15	
20.025J	Genetics, 12	
Restricted Electives:		48
Two of the following seven subjects: [2]		
7.06	Metazoan Cell Biology, 12; 7.01 or 7.05	
7.21	Microbial Physiology, 12; 7.05	
7.71J	Biophysical Chemistry, 12; 5.60, 7.05	
20.006	Chemicals and Human Disease, 12	
20.022J	Human Physiology, 12; 7.05	
20.024	Pharmacology and Toxicology, 9; 5.42, 7.05	
20.026	Mechanisms of Pathogenesis, 12; 7.05, 7.03	
	plus	
24 units of research, either as letter-grade UROP (20.011 and 20.012) or as Course 20 undergraduate thesis (20.ThU).[3]		
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.

Graduate Study

Bachelor of Science in Life Sciences
Course VII-B
Applied Biology Curriculum

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 5.11, 5.60, and 7.05 in the Departmental Program.		
The Laboratory Requirement can be satisfied by 20.002 in the Departmental Program.		
Departmental Program		
Subject names below are followed by credit units, and by prerequisites if any (corequisites in italics)		
Required Subjects:		110
5.11	Principles of Chemical Science, 12	
5.12	Organic Chemistry I, 12; 5.11	
5.60	Chemical Thermodynamics, 12; *18.02*	
7.01	General Biology, 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; 18.001 or 18.01 or 18.011 or 18.012	
20.002	Laboratory in Applied Biology, 14	
20.025J	Genetics, 12	
Restricted Electives:		36
Three of the following five subjects:[1]		
7.06	Metazoan Cell Biology, 12; 7.01 or 7.05	
7.21	Microbial Physiology, 12; 7.05	
7.71J	Biophysical Chemistry, 12; 5.60, 7.05	
20.022J	Human Physiology, 12; 7.05	
20.024	Pharmacology and Toxicology, 9; 5.42, 7.05	
	plus	
24 units of research, either as letter-grade UROP (20.011 and 20.012) or as Course 20 undergraduate thesis (20.ThU).[2]		24
Unrestricted Electives		60
Total Units Required for the S.B. Degree		362

1
A graduate subject from the following list may be substituted for one of these five subjects: 20.112, 20.511J, 20.611, 20.734, 20.801.

2
Completion of this requirement involves a written report for 20.011/20.012, or a thesis for 20.ThU.

The Department of Applied Biological Sciences offers graduate work leading to the Master of Science, Doctor of Philosophy, and Doctor of Science in a wide range of fields as indicated by the detailed subject descriptions in Chapter VIII. Advanced work may be pursued in the following areas:

Biotechnology. The program in Biotechnology prepares students for careers in research involving the application of modern biology, biochemistry, and engineering to problems in the production of chemicals, foods, and medicinal agents.

The objective of the Biotechnology program is to provide broad training in microbiology, biology, biochemistry, and engineering. The program combines course instruction in these subjects with experimental applications to research problems.

Formal course work for the doctoral degree centers on the core Biotechnology courses with appropriate supporting course work from the Departments of Applied Biological Sciences, Chemical Engineering, Biology, and Chemistry.

Biochemical Engineering. A program in Biochemical Engineering is offered leading to the Master of Science and doctoral degrees. Integration of studies in biological sciences with engineering is emphasized, with particular attention to industrial microbiology and fermentation processes. Research projects in Biochemical Engineering include: continuous culture of microorganisms, microbial utilization of renewable resources, enzyme production and enzyme technology, mammalian tissue cultures, use of molecular genetics to improve industrial microorganisms, performance characterization of polymers and biomaterials, and drug delivery techniques.

Toxicology. A program is offered leading to the Master of Science and doctoral degrees. The multidisciplinary training program consists of fundamental course work in biology and chemistry followed by courses in toxicology at molecular and cellular levels. Typical research areas include: chemical carcinogenesis; tumor promotion; metabolism of drugs, chemical carcinogens and other toxins; development of approaches to the direct measurement of exposure to toxic agents in humans; and structural elucidation of chemically modified DNA and its relationship to genetic change in bacteria and human cells.

Neural and Endocrine Regulation. A program is offered which leads to the Master of Science and doctoral degrees in Neural and Endocrine Regulation. The program provides graduate students with an opportunity to acquire a broad background in physiologic and metabolic regulation, and a detailed knowledge of brain function in mammals. Its principal objective is the training of independent basic-science and clinical investigators who explore the mechanisms by which the brain and endocrine system maintain homeostasis, control endocrine and reproductive function, and mediate the responses of the body to environmental inputs. The program offers advanced study in the fields of neuroendocrinology, neuropharmacology, neurochemistry, and psychopharmacology.

Nutritional Biochemistry and Metabolism. This program leads to the Master of Science and doctoral degrees. It trains graduate students in biochemistry and physiological chemistry as these apply to metabolic and nutritional problems in normal and pathological states. Research projects in this area include: regulation of protein synthesis and turnover, validation of tracer techniques using radioactive and stable isotopes for metabolic and nutritional studies, and nutrition and drug treatment of hyperlipoproteinemia.

Entrance Requirements for Graduate Study

To qualify for graduate study in the Department, an applicant should have a Bachelor's degree in science or engineering, or a professional degree such as the M.D. or D.V.M. In addition to the General Institute requirements outlined in Chapter IV, the following subjects are required: 8.01, 8.02 (Physics I &II); 18.01, 18.02 (Calculus I & II): and two terms of Organic Chemistry. The Graduate Record Exam (GRE) is also required of all applicants.

Master of Science

The S.M. degree is awarded in Applied Biological Sciences and in Biochemical Engineering. The requirements for the S.M. in Applied Biological Sciences include the following Departmental entrance subjects — 20.025J or 7.08, 5.60 or 10.13, and 7.05 or Advanced Biochemistry course; the following core courses — 20.111 Analytical Practices in Biochemistry, 20.112 Control of Cellular Metabolism, and 20.113 Principles of Applied Biology; and at least two 'A' level elective graduate courses.

Departmental entrance subjects for the S.M. in Biochemical Engineering are the same as those listed for the Applied Biological Sciences program, plus 10.301. Core courses include 20.811J Biochemical Engineering, 20.812J Biochemical Engineering Laboratory, 20.821 Industrial Microbiology, and 20.822 Industrial Microbiology Laboratory. Students must also take at least three elective subjects from a designated group of 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 Departmental faculty member.

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 which 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, taken during the second year of graduate study, 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 above. Research progress is evaluated periodically by the thesis advisory committee, which also hears the student's oral defense of the completed thesis.

The written general examination for students in Biochemical Engineering is prepared by faculty members from the Departments of Applied Biological Sciences, Biology, and Chemical Engineering. Faculty members from these departments also make up the thesis committee for students in Biochemical Engineering.

Assistantships and Fellowships

Financial assistance is available to qualified applicants in the form of research assistantships, traineeships, and a limited number of fellowships, subject to availability of funds. Research assistantships are provided from grants obtained by members of the faculty for work on specific research projects.

Inquiries

Additional information concerning academic programs, research activities, admissions, financial aid, assistantships and fellowships may be obtained by writing to Student Office, Department of Applied Biological Sciences, Professor Steven R. Tannenbaum, Room 16-330, MIT, Cambridge, Massachusetts 02139, (617) 253-5804.

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.
Professor of Genetics

Gene M. Brown, Ph.D.
Professor of Biochemistry
Dean, School of Science

John Machlin Buchanan, Ph.D., D.Sc.
John and Dorothy Wilson Professor of Biochemistry

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.
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Rudolf Jaenisch, M.D.
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Har Gobind Khorana, Ph.D.
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Jonathan Alan King, Ph.D.
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Jerome Ysrael Lettvin, M.D.
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Harvey Franklin Lodish, Ph.D.
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Professor of Biology and Medicine

Salvador Edward Luria, M.D., D.Sc.
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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.
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Alexander Rich, M.D.
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William Thompson Sedgwick Professor of Biology

Phillips Wesley Robbins, Ph.D.
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Robert Daniel Rosenberg, M.D., Ph.D.
Professor of Medicine and Biology

Paul Reinhard Schimmel, Ph.D.
Professor of Biochemistry and Biophysics

Phillip Allen Sharp, Ph.D.
Class of 1941 Professor of Biology
Director, Center for Cancer Research

Ethan Royal Signer, Ph.D.
Professor of Biology

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

Christopher Thomas Walsh, Ph.D.
Professor of Chemistry and Biology
Uncas and Helen Whitaker Professor in the Whitaker College
Head, Department of Chemistry

Robert Allen Weinberg, Ph.D.
Professor of Biology

Associate Professors

Leonard Pershing Guarente, Ph.D.
Associate Professor of Biology

Monty Krieger, Ph.D.
Associate Professor of Molecular Genetics

Ronald Davies Graham McKay, Ph.D.
Edward J. Poitras Associate Professor in Human Biology and Experimental Medicine

Richard Charles Mulligan, Ph.D.
Associate Professor of Molecular Biology

William G. Quinn, Ph.D.
Associate Professor of Neurobiology

Robert Thomas Sauer, Ph.D.
Associate Professor of Biochemistry

Assistant Professors

Steven J. Burden, Ph.D.
Assistant Professor of Biology

Brent Hartman Cochran, 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

David Henri Raulet, Ph.D.
Assistant Professor of Immunology

Donald C. Rio, Ph.D.
Assistant Professor of Biology

H. Earl Ruley, Ph.D.
Assistant Professor of Biology

Hee-Sup Shin, M.D., Ph.D.
Assistant Professor of Biology

Richard Allen Young, Ph.D.
Assistant Professor of Biology

Lecturer

Erika A. Hartwieg

Administrative Officer

Cynthia D. Kowal, B.A.

Assistant to the Department Head

Maija K. Ahlquist, B.A.

Operations Administrator

Thomas A. Lynch

Senior Research Associate

Daniel H. Levin, Ph.D.

Senior Research Scientist

Andrew H-J. Wang, Ph.D.

Principal Research Scientists

Gary J. Quigley, Ph.D.
Joan Lucia Suit, Ph.D.

Research Scientists

Duncan Richard Paton, Ph.D.
Leon G. Shiman, Ph.D.
Arlene R. Wyman, Ph.D.

Postdoctoral Associates

Alison Adams, Ph.D.
Gary Barsomian, Ph.D.
John Battista, Ph.D.
Christopher Bazinet, Ph.D.
William G. Bendena, Ph.D.
Timothy Bestor, Ph.D.
Martina Boersch-Supan, Ph.D.
Julian F. Bond, Ph.D.
Frank Boschelli, Ph.D.
Caroline A. Breitenberger, Ph.D.
Katherine M. Call, Ph.D.
Clare Chatot, Ph.D.
Caroline Donnally, Ph.D.
Harold J. Drabkin, Ph.D.
Edward G. Fey, Ph.D.
Daniel J. Finley, Ph.D.
Thomas Friedrich, Ph.D.
Daniela S. Gerhard, Ph.D.
Mark R. Heller, Ph.D.
Tsai-Hsia Hong, Ph.D.
Yun-Pung Hsu, Ph.D.
Parmjit S. Jat, Ph.D.
Kendall L. Knight, Ph.D.
Jone-Long Ko, Ph.D.
David M. Kranz, Ph.D.
Avraham Laban, Ph.D.
Pamela Larsen, Ph.D.

Department of Biology

(Course 7)

Yen Li, Ph.D.
Susan Long, Ph.D.
Mary F. Lopez, Ph.D.
Keiji Maeda, Ph.D.
Thierry J-P Marcel, Ph.D.
Kasuo Maruyama, Ph.D.
Carole A. Mikoryak, Ph.D.
Kelley W. Moremen, Ph.D.
Alexander Ninfa, Ph.D.
Pamela Norton, Ph.D.
Peter Orlean, Ph.D.
Lawrence J. Peck, Ph.D.
Peter Prevelige, Ph.D.
N. Narayana Rao, Ph.D.
Linda S. Reidl, Ph.D.
Edward Reilly, Ph.D.
Regina M. Reilly, Ph.D.
Lawrence J. Reitzer, Ph.D.
Bruce Lee Rogers, Ph.D.
Syamal Roy, Ph.D.
Jean Schwarzbauer, Ph.D.
John M. Sedivy, Ph.D.
Nava Segev, Ph.D.
Ruth Starzyk, Ph.D.
Mary Ann Stepp, Ph.D.
Judith L. Toffenetti, Ph.D.
Suh-der Tsen, Ph.D.
Robert J. Villafane, Ph.D.
Philip A. Wendler, Ph.D.
Mary E. White-Scharf, Ph.D.
Michael L. Woodruff, Ph.D.

Professors Emeriti

Eugene Bell, Ph.D.
Professor of Biology, Emeritus

Bernard Sidney Gould, Ph.D.
Professor of Biochemistry, 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.

Undergraduate Study

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.

Bachelor of Science in Life Sciences
Course VII-B

The curriculum of Course VII-B offers specialization in Applied Biology. Students electing this area should consult with the Department of Applied Biological Sciences before registration. Although 5.311 Introductory Chemical Experimentation is not a Departmental Requirement, it is particularly useful for students whose interest is in biochemistry; it may also be required for admission to medical school. As part of their elective programs, students are encouraged to enroll in the more advanced subjects offered by the Department. The details of the curriculum requirements for Course VII-B, Applied Biology, are given under the Department of Applied Biological Sciences in this chapter.

Additional information regarding undergraduate academic programs, research opportunities, admissions, financial aid, etc., may be obtained from Biology Headquarters, Undergraduate Secretary, Room 56-511, MIT, Cambridge, Massachusetts 02139, (617) 253-4701.

Graduate Study

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 7.01 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, 12	
7.011	Introduction to Experimental Biology, 15; 7.01 or 7.05	
7.03J	Genetics, 12	
7.05	General Biochemistry, 12; 5.12	
7.08	Cell and Molecular Biology, 12; 7.03J, 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	
7.15	Experimental Molecular Biology: Biotechnology I, 24; 7.011, 7.03J, 7.05	
7.16	Experimental Molecular Biology: Biotechnology II, 24; 7.011, 7.03J, 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. 20.002 may be substituted for 7.011.
2
Students who take 5.11 to fulfill the General Institute Requirement for Chemistry must take 12 additional units of Unresticted Electives.

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 7.01 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:		110
5.11	Principles of Chemical Science, 12	
5.12	Organic Chemistry I, 12; 5.11	
5.60	Chemical Thermodynamics, 12; *18.02*	
7.01	General Biology, 12	
7.011	Introduction to Experimental Biology, 15; 7.01 or 7.05	
7.03J	Genetics, 12	
7.05	General Biochemistry, 12; 5.12	
7.08	Cell and Molecular Biology, 12; 7.03J, 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	
7.15	Experimental Molecular Biology: Biotechnology I, 24; 7.011, 7.03J, 7.05	
7.16	Experimental Molecular Biology: Biotechnology II, 24; 7.011, 7.03J, 7.05	
Unrestricted Electives		60
Total Units Required for the S.B. Degree		362

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. 20.002 may be substituted for 7.011.

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 requlation 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. There are no specific Departmental programs for the degree, since the subjects required vary with the field of specialization. Students select their own programs, according to certain broad principles, after consultation with the Graduate Committee 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.

Teaching and Research Assistantships

A number of qualified students are appointed each year as teaching or research assistants. Research assistants may be permitted to use the results of their assigned research work in graduate theses, with the possible acceleration of their programs. In addition, a number of predoctoral and postdoctoral fellowships are available in cell biology, microbiology, physiology, biochemistry, and biophysics.

Inquiries

Additional information regarding graduate academic programs, research activities, admissions, financial aid, and assistantships may be obtained from Biology Headquarters, Graduate Secretary, Room 56-511, MIT, Cambridge, Massachusetts 02139, (617) 253-4701.

Department of Chemistry

Christopher Thomas Walsh, Ph.D.
Professor of Chemistry and Biology
Uncas and Helen Whitaker Professor in the Whitaker College
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.
Arthur C. Cope 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

James Lloyd Kinsey, 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.
Professor of Chemistry

Robert James Silbey, Ph.D.
Professor of Chemistry

Jeffrey Irwin Steinfeld, Ph.D.
Professor of Chemistry,

John Stewart Waugh, Ph.D.
Arthur Amos Noyes Professor of Chemistry

Mark Stephen Wrighton, Ph.D.
Frederick G. Keyes Professor of Chemistry

Associate Professors

Rick Lane Danheiser, Ph.D.
Associate Professor of Chemistry

William Richard Roush, Ph.D.
Associate Professor of Chemistry

Assistant Professors

Stephen Leffler Buchwald, Ph.D.
Rogers and Georges Firmenich Career Development Assistant Professor of Natural Products Chemistry

Sylvia Teresse Ceyer, Ph.D.
Class of 1943 Career Development Assistant Professor of Chemistry

Keith Adam Nelson, Ph.D.
Assistant Professor of Chemistry

Philip Wirth Phillips, Ph.D.
Assistant Professor of Chemistry

Lecturer

Dagmar Ringe, Ph.D.

Principal Research Scientist

Catherine Elizabeth Costello, Ph.D.

Technical Instructor

James Alexander Simms

Executive Associate

Lawrence William Ryan, Jr.

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

Avery Adrian Morton, Ph.D.
Professor of Organic Chemistry, Emeritus

John Clark Sheehan, Ph.D., Sc.D.
Professor of Organic Chemistry, Emeritus

Clark Conkling Stephenson, Ph.D.
Professor of Chemistry, Emeritus
Senior Lecturer

Charles Gardner Swain, Ph.D.
Professor of Organic Chemistry, Emeritus

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 which give them more detailed knowledge in the areas in which they wish to specialize. Students who plan to enter industry may elect subjects which offer the fundamentals in a selected field of science, engineering, or the humanities and social sciences. Five-year programs may also be elected which 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 also 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 also 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 which 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, analytical, 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 which is pertinent to long-range research interests.

Written major examinations are cumulative. Separate examinations in biological, inorganic, 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

William Francis Brace, Ph.D.
Cecil and Ida Green Professor of Geology
Head of the Department

Professors

Claude J. Allegre, Ph.D.
Professor of Geochemistry
(Visiting)

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

Claude J. Frankignoul, Ph.D.
Professor of Oceanography
(Visiting)

Frederick August Frey, Ph.D.
Professor of Geochemistry

Stanley Robert Hart, Ph.D.
Professor of Geology and Geochemistry

Thomas Hillman Jordan, Ph.D.
Robert R. Shrock Professor of Earth and Planetary Sciences

Richard Siegmund Lindzen, Ph.D.
Alfred P. Sloan Professor of Meteorology

Edward Norton Lorenz, Sc.D.
Professor of Meteorology

Theodore Richard Madden, Ph.D.
Professor of Geophysics

Erik L. Mollo-Christensen, Sc.D.
Professor of Meteorology
(Visiting)

Reginald Edward Newell, Sc.D.
Professor of Meteorology

Gordon Hemenway Pettengill, Ph.D.
Professor of Planetary Physics
Director, Center for Space Research

Ronald George Prinn, Sc.D.
Professor of Meteorology
(On leave, spring)

M. Gene Simmons, Ph.D.
Professor of Geophysics

Sean Carl Solomon, Ph.D.
Professor of Geophysics

John Brelsford Southard, Ph.D.
Professor of Geology
(On leave, spring)

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

Joseph Broughton Walsh, Ph.D.
Professor of Geophysics
(Visiting)

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

Kerry Andrew Emanuel, Ph.D.
Associate Professor of Meteorology

Glenn Richard Flierl, Ph.D.
Associate Professor of Oceanography

Timothy L. Grove, Ph.D.
Associate Professor of Petrology

Marcia K. McNutt, Ph.D.
Associate Professor of Marine Geophysics
(On leave)

Barry Eaton Parsons, Ph.D.
Associate Professor of Geophysics
(Visiting)

Paola Malanotte Rizzoli, Ph.D.
Associate Professor of Oceanography

Assistant Professors

Randall M. Dole, Ph.D.
Assistant Professor of Meteorology

Gregory L. Duckworth, Ph.D.
Assistant Professor of Geophysics

J. Brian Evans, Ph.D.
Assistant Professor of Geophysics

Kip V. Hodges, Ph.D.
Assistant Professor of Geology

David C. Jewitt, Ph.D.
Assistant Professor of Planetary Science

Sandro Rambaldi, Ph.D.
Assistant Professor of Meteorology
(Visiting)

Leigh H. Royden, Ph.D.
Assistant Professor of Geology and Geophysics
Kerr McGee Career Development Professor

Earle R. Williams, Ph.D.
Assistant Professor of Meteorology

Jack Wisdom, Ph.D.
Assistant Professor of Planetary Science

William R. Young, Ph.D.
Cecil and Ida Green Career Development Assistant Professor of Oceanography

Instructor

Linda M. French, Ph.D.

Senior Lecturers

John Carl Foster, Ph.D.
Richard D. Rosen, Ph.D.
Joseph E. Salah, Ph.D.

Lecturers

John M. Holt, Ph.D.
William L. Oliver, Ph.D.

Honorary Lecturer

Cecil H. Green, S.M., D.S.C., LL.D.

Administrative Officer

Douglas Pfeiffer, M.B.A.

Administrative Staff

Carol Ann Ramey

Senior Research Scientists

Peter Molnar, Ph.D.

Nobumichi Shimizu, D.Sc.
Director, Ion Probe Facility

Principal Research Scientists

Chuen Hon Cheng, Ph.D.
Vernon F. Cormier, Ph.D.
M. Bruce Fegley, Ph.D.
Richard G. French, Ph.D.
Robert W. King, Jr., Ph.D.
Marcia K. McNutt, Ph.D.
Christopher I. Measures, Ph.D.

Research Associates

Richard Abbott, Ph.D.
Eric Bergman, Ph.D.
Teresa Bowers, Ph.D.
Kenneth Creager, Ph.D.
Edward Dunham, Ph.D.
Peter Ford, Ph.D.
Gilles Garcia, Ph.D.
Levent Gulen, Ph.D.
Hyman Hartman, Ph.D.
Pillalamarri Ila, Ph.D.
Katherine Kadinsky-Cade, Ph.D.
Gary Klinkhammer, Ph.D.
Ralph Markson, Ph.D.
Robert McCaffrey, Ph.D.
Stephen Meacham, Ph.D.
Steven Recca, M.S.
Robert Reilinger, Ph.D.
Roger Turpening, Ph.D.
Roy Wilkens, Ph.D.
Jane Hsiung Wojcik, Ph.D.

Research Engineers

Kenneth Burrhus
Walter Cook, M.S.
Spiros Geotis
George Keough

Research Specialists

Carol Blackway, B.S.
Susan Chapnick, M.S.
James Fullmer, Ph.D.
Barbara Grant, M.S.
Mitra Khadem, B.S.
Charmaine King, B.S.
David Krowitz, B.S.
Jane Maloof, B.S.
Jeffrey Mann, M.S.
Linda Meinke, B.S.
James Mendelson, M.S.
Oliver Newell
Diana Spiegel, M.S.

Research Staff, Administrative

Sara H. Brydges, B.A.
Jane S. McNabb, B.A.
Albert L. Taylor

Postdoctoral Associates

Yehuda Agnon, Ph.D.
Yves Bernabe, Ph.D.
Wafik Beydoun, Ph.D.

Department of Earth, Atmospheric, and Planetary Sciences

(Course 12)

Andrew Campbell, Ph.D.
Paul Huang, Ph.D.
Shane Ingate, Ph.D.
Mitsuhiro Kawase, Ph.D.
Venkataramanaiah Krishnamurthy, Ph.D.
Chang-Bok Lee, Ph.D.
Sumant Nigam, Ph.D.
Martin Palmer, Ph.D.
Reiner Schlitzer, Ph.D.
Denis Schmitt, Ph.D.
Henry Selkirk, Ph.D.
Roberta Young, Ph.D.

Visiting Scientists

Abdullatif Barka, Ph.D.
W. Roger Buck, Ph.D.
Anton Dainty, Ph.D.
Fatih Güler, M.S.
Sadiye Güler, M.S.
Jung Mo Lee, M.S.
Xianlang Li, B.S.
Daniel Rothman, Ph.D.
John Nabelek, Ph.D.
Hans-Rainier Schneider, Ph.D.
Orhan Sen, Ph.D.
Pierre Tarif, Ph.D.
Yun Sheng Zhu, M.S.

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

Henry Garrett Houghton, Sc.D.
Professor of Meteorology, Emeritus

Patrick Mason Hurley, Ph.D.
Professor of Geology, 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 utilize 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, emphasizing 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, 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 *in situ* physical and chemical measurements, laboratory studies, and theoretical treatments. 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 radar and radio observatory, 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.

Undergraduate Study

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 the second year to obtain 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. 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; 1.05, 18.03	
3.11	Mechanics of Materials I, 12; 8.01, 18.02	
5.61	Physical Chemistry, 12; 8.02, 18.02	
18.354	Fluid Mechanics, 12; 18.04 or 18.075 or 18.302	
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.

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 which lead 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 Secretary, Room 54-912, 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.

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; 1.05, 18.03	
3.11	Mechanics of Materials I, 12; 8.01, 18.02	
5.61	Physical Chemistry, 12; 8.02, 18.02	
18.354	Fluid Mechanics, 12; 18.04 or 18.075 or 18.302	
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

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. Advanced work in these fields leads to the Master of Science in Earth and Planetary Sciences, in Meteorology, or in Oceanography, the Doctor of Philosophy, or the Doctor of Science with a thesis in the field of specialization.

In earth and planetary sciences, graduate students pursue both theoretical and experimental aspects. 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 meteorology and oceanography, emphasis in the graduate program is given to the theoretical and quantitative approach, supplemented by empirical information and quantitative data analysis. Graduate study therefore includes a mixture of theoretical and descriptive courses, 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 joint 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.

Master of Science in Meteorology or in Oceanography

The graduate ("A") subjects required for the Master of Science may be selected from those offered in meteorology or in oceanography and those in related fields offered by other departments. Undue specialization in one branch of either field is discouraged. There are no foreign language requirements for the degree. Master's students 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, because of the importance of communications with foreign scientists, it is strongly urged that candidates for the doctorate acquire intermediate competence in one or more languages. A specialized program of

Center for Meteorology and Physical Oceanography

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 which 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 Secretary, Room 54-912, MIT, Cambridge, Massachusetts 02139, (617) 253-3381.

Meteorology

Formal subjects of instruction are offered in most principal areas of meteorology, and usually are 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, equipped with data processing facilities, and also has a synoptic laboratory which receives and archives current weather data from the National Meteorological Center. The data cover large parts of the globe and are generally in computer-compatible format. The Center also has a computer facility with a medium-sized computer and peripheral equipment, and remote terminals which enable 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 in addition to the many informal contacts.

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 field and laboratory 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.

Department of Mathematics

Arthur Paul Mattuck, Ph.D.
Class of 1922 Professor
of Mathematics
Head of the Department

Franklin Paul Peterson, Ph.D.
Professor of Mathematics
Chairman, Committee on Pure Mathematics

Willem Van Rensselaer Malkus, Ph.D.
Professor of Applied Mathematics
Chairman, Committee on Applied Mathematics

Professors

Nesmith Cornett Ankeny, Ph.D.
Professor of Mathematics
(On leave, fall)

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 Applied Mathematics

Daniel Z. Freedman, Ph.D.
Professor of Applied Mathematics
(On leave, spring)

Harvey Philip Greenspan, Ph.D.
Professor of Applied Mathematics
(On leave, spring)

Victor William Guillemin, Ph.D.
Professor of Mathematics
(On leave, spring)

Sigurdur Helgason, Ph.D.
Professor of Mathematics

Kenneth Myron Hoffman, Ph.D.
Professor of Mathematics

Victor Kač, Ph.D.
Professor of Mathematics

Daniel Marinus Kan, Ph.D.
Professor of Mathematics

Steven Kleiman, Ph.D.
Professor of Mathematics

Daniel J. Kleitman, Ph.D.
Professor of Applied Mathematics

Bertram Kostant, Ph.D.
Professor of Mathematics

Chia-Chiao Lin, Ph.D.
Institute Professor
Professor of Applied Mathematics

George Lusztig, Ph.D.
Professor of Mathematics

Richard Burt Melrose, Ph.D.
Professor of Mathematics

Haynes P. Miller, Ph.D.
Professor of Mathematics

James Raymond Munkres, Ph.D.
Professor of Mathematics

Daniel Gray Quillen, Ph.D.
Norbert Wiener Professor of Mathematics
(On leave)

Hartley Rogers, Jr., Ph.D.
Professor of Mathematics

Gian-Carlo Rota, Ph.D.
Professor of Applied Mathematics and Philosophy

Gerald Enoch Sacks, Ph.D.
Professor of Mathematical Logic

Richard Donald Schafer, Ph.D.
Professor of Mathematics

Irving Ezra Segal, Ph.D.
Professor of Mathematics
(On leave, spring)

Isadore Manual Singer, Ph.D.
John D. MacArthur 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

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, spring)

David Alexander Vogan, Ph.D.
Professor of Mathematics

Associate Professors

David Jay Anick, Ph.D.
Associate Professor of Mathematics

Anders Björner, Ph.D.
Associate Professor of Applied Mathematics
(On leave)

Sy David Friedman, Ph.D.
Associate Professor of Mathematics

David S. Jerison, Ph.D.
Associate Professor of Mathematics

Frank Thomson Leighton, Ph.D.
Associate Professor of Applied Mathematics

Greta M. Ljung, Ph.D.
Associate Professor of Applied Mathematics
(Visiting)

Frank Morgan, Ph.D.
Cecil and Ida Green Career Development Associate Professor of Mathematics

Bent Ørsted, Ph.D.
Associate Professor of Mathematics
(Visiting, fall)

Rodolfo Reuben Rosales, Ph.D.
Associate Professor of Applied Mathematics

Michael Sipser, 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

Ding Zhu Du, Ph.D.
Assistant Professor of Applied Mathematics
(Visiting)

Zoltan Furedi, Ph.D.
Assistant Professor of Applied Mathematics

Mark D. Haiman, Ph.D.
Assistant Professor of Applied Mathematics

Iris Marie Mack, Ph.D.
Assistant Professor of Applied Mathematics
(Visiting)

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 A. Shmoys, Ph.D.
Assistant Professor of Applied Mathematics

Lloyd Nicholas Trefethen, Ph.D.
Assistant Professor of Applied Mathematics

Nicholas P. Warner, Ph.D.
Assistant Professor of Applied Mathematics

Stephane L. Zaleski, Ph.D.
Assistant Professor of Applied Mathematics

C. L. E. Moore Instructors

Steven R. Costenoble, Ph.D.
Bennett Chow, Ph.D.
Robin Forman, Ph.D.
(On leave)
Daniel S. Freed, Ph.D.
Peter N. Heller, Ph.D.
(On leave)
Mark S. Legrand, Ph.D.
Martin Lustig, Ph.D.
Gordana Matic, Ph.D.
Richard Montgomery, Ph.D.
Monica Petri, Ph.D.
William T. Shaw, Ph.D.
Robert D. Thompson, Ph.D.
Dave Witte, Ph.D.
Michael Wolf, Ph.D.
Zhengfang Zhou, Ph.D.
Roger Zierau, Ph.D.

Instructors in Applied Mathematics

Yehuda Agnon, Ph.D.
Kwok Wing Chow, Ph.D.
Patrice LeGal, Ph.D.
Er-Cheng Tsai, Ph.D.
Mai Zhou, Ph.D.

Lecturer

Jean-Dominique Deuschel, Ph.D.

Department of Mathematics

(Course 18)

Undergraduate Study

Administrative Officer

James Edward Dalton

Administrative Assistants

Joanne E. Murray, B.S.
Phyllis Ruby, A.B.
Marjorie Tyler

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

William Ted Martin, Ph.D.
Professor of Education and 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 Proctor Wadsworth, 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 which, 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 which deal 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 or 18.710, 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 also listed in the subject description.

1 A list of acceptable subjects is available in Room 2-108

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.

Some flexibility is allowed in this program. For instance, students may, with permission, substitute 18.100A for 18.100B; and they may substitute 18.710 Abstract Linear Algebra, plus 18.703 Modern Algebra, for the recommended algebra sequence 18.701-18.702. Similarly, a thesis or (less desirably) a first-year graduate subject may be substituted for the Seminar.

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		
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 also 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. They may also substitute 18.701 Algebra I for 18.06 Linear Algebra, in which case 18.702 Algebra II may be used as a Restricted Elective.

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	
18.414J	Theory of Algorithms, 12; 18.310, 18.06 or 18.710	
6.001	Structure and Interpretation of Computer Programs, 15	
6.034	Artificial Intelligence, 12; 6.001	
One of the following two subjects:		
18.06	Linear Algebra, 12; 18.02	
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, 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.

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 Subjects 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 or 18.710, 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 also 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 also 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

18.414J Theory of Algorithms, 12; 18.310, 18.06 or 18.710

6.001 Structure and Interpretation of Computer Programs, 15

6.034 Artificial Intelligence, 12; 6.001

One of the following two subjects:
18.06 Linear Algebra, 12; 18.02
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

1 A list of acceptable subjects is available in Room 2-108.

Graduate Study

The Department offers programs covering a broad range of topics which lead to the Master of Science, the Doctor of Philosophy, and the Doctor of Science; however, students are admitted to a master's program only in statistics. 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 which approximates 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.

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Head of the Department

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Frank E. Taylor, Ph.D.

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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.

It is suggested that in the second year 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 second year, a student will also get a first exposure to 8.04 Quantum Physics, and 8.044 Statistical Physics. (Students of the class years 1986 and 1987 have the option of using either 8.044 or 8.08 to satisfy the requirement in statistical physics. For students in the class of 1988 and beyond, 8.044 is the required subject.)

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 also given 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 and 8.07.

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**[1] 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 Dr. Alan J. Lazarus, c/o the Physics Undergraduate Office, Room 4-352, MIT, Cambridge, Massachusetts 02139, (617) 253-4841.

1
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 also given 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 and 8.07.

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 observations across the entire electromagnetic spectrum, with principal emphasis on the radio, infrared, and X-ray parts, where modern electronic methods must be 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.

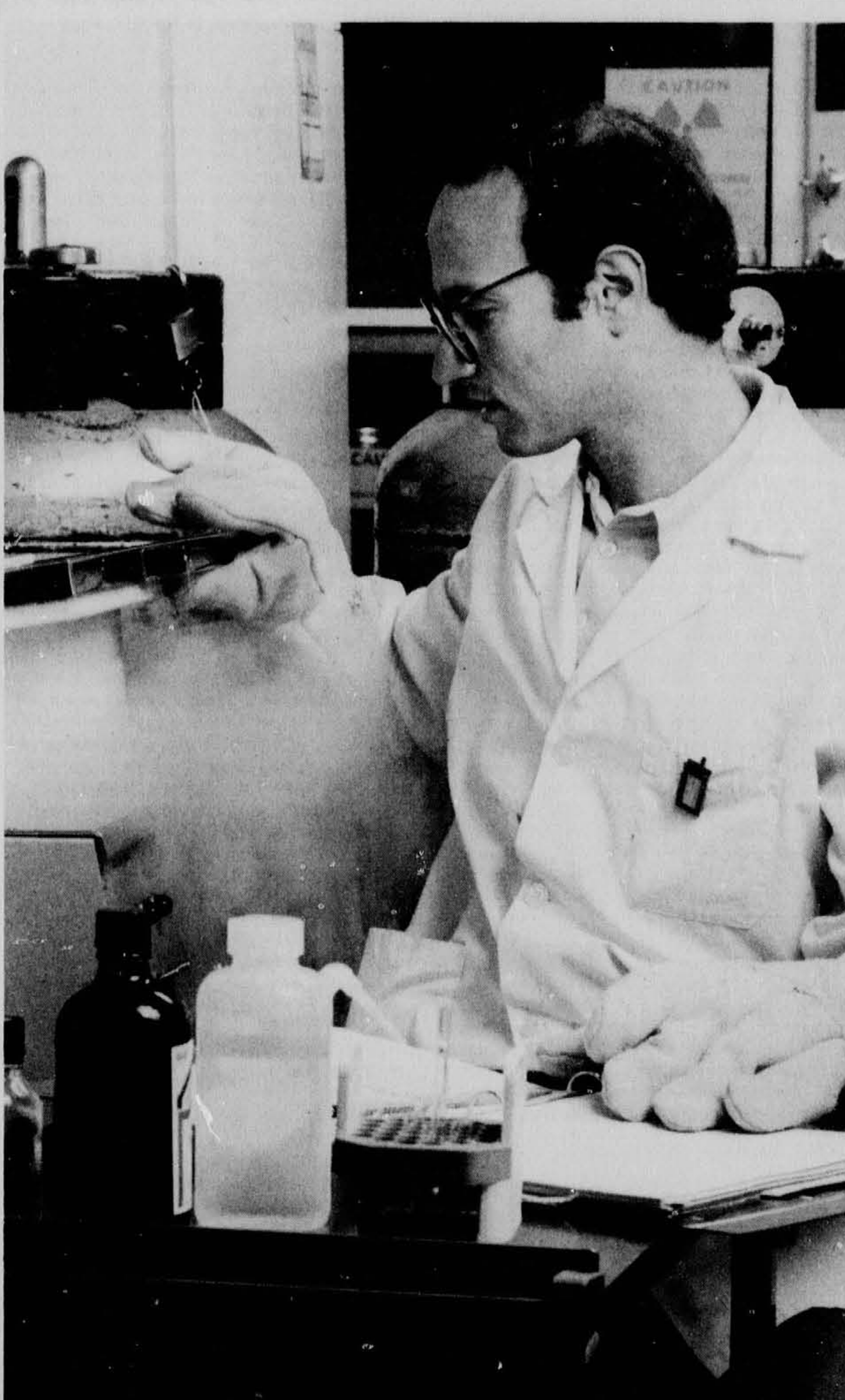
Entrance Requirements for Graduate Study

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.

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, engineering, and management 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, computer science, cognitive science, economics, and management. 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 four intellectual foci, which now serve as the basis for its divisions. These are the newly formed Department of Brain and Cognitive Sciences, the program in Biological Imaging, the program in Human Biology and Experimental Medicine, and the program in Health Policy and Management. 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 Ph.D. program in health policy and management (described here) admitted its first class in September 1983. The interdepartmental Ph.D. program in Biomedical Engineering also operates under the auspices of the College. (See the program description in Chapter VI.) In addition, the Ph.D. program in Radiological Sciences is operated under the joint auspices of the College and the Department of Nuclear Engineering.

The Doctoral Program in Brain and Cognitive Sciences

The newly 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

The new department will enhance MIT's ongoing interdisciplinary efforts to understand the human brain. The study of the complexities of the brain requires an approach which combines 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 will follow a curriculum which 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 Health Policy and Management

The goal of this program is to generate an understanding of the managerial/institutional context that determines the allocation of health-care resources, as well as an understanding of the scientific and technological issues in medicine. The program draws on faculty from the Departments of Economics and Political Science and the Sloan School of Management, as well as other departments and Schools throughout the Institute.

The program offers a three- to four-year doctoral curriculum for new entrants into the health policy and management field. The program may be completed in a shorter time by matriculants with advanced preparation.

The core curriculum of the program provides the scientific methodology and tools needed to understand health policy and management, and offers alternative perspectives on ways to resolve policy and management issues in the field. Degree candidates are required to specialize in a related underlying discipline. Each Ph.D. candidate develops an advanced track of disciplinary study, such as economics, political science, or management. Students may design alternative courses, subject to faculty approval. In addition, each doctoral student is expected to carry out an independent research project, preferably in a clinical setting. The doctoral dissertation generally requires one year of field study and/or analysis, after completion of the qualifying examinations.

Applications are encouraged from physicians, medical students, and others who have completed two years of basic medical sciences or who demonstrate equivalent knowledge or preparation. All successful candidates will receive stipends to defray tuition and living expenses from funds granted to MIT by the Henry J. Kaiser Family Foundation. Applications for admission to the program may be obtained from Stan N. Finkelstein, M.D., Director, Laboratory for Health Care Studies, E25-143, MIT, 77 Massachusetts Ave., Cambridge, Massachusetts 02139, (617) 253-5285.

The Doctoral Program in Radiological Sciences

A new graduate program entitled Radiological Sciences has been developed to educate students in the varied applications of radiation in medicine and to expand the research frontiers in this area. In addition to a central concern with ionizing radiation, Radiological Sciences encompasses more recent technologies employing other forms of radiation, such as ultrasound and laser light, and other diagnostic techniques, such as nuclear magnetic resonance. The curriculum in Radiological Sciences is a four- to five-year commitment leading to the Ph.D. or Sc.D. degree awarded by MIT.

Students in Radiological Sciences may pursue their academic and research objectives in any one of four specialty areas: medical therapy, imaging and diagnostic technology, radiation biophysics, and radiopharmaceutical chemistry. While most core Radiological Sciences subjects will be taken at MIT, student research can be conducted at Harvard-affiliated hospitals, Harvard School of Public Health, and MIT, depending on the student's specialty area.

In the area of medical therapy, students will probe questions and methodologies which have an impact on human disease treatment. Imaging and diagnostic technology research is carried out mainly at the hospitals where innovative methods for the noninvasive examination of internal body structure and physiology are explored. A major goal in this area of study is the development and improvement of radiological diagnostic techniques.

In the area of radiation biophysics, research is focused upon radiation effects at the cellular and subcellular levels in an effort to better understand the basic biological response to irradiation. Several of the current radiation biophysics pursuits are conducted at the electron microscope level and emphasize 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 the Harvard-affiliated hospitals offer outstanding research facilities in this area of study.

The program in the Radiological Sciences is structured as follows: The student should apply for admission to the MIT Department of Nuclear Engineering. If admitted, the student will pursue a graduate program leading to a master's degree in Nuclear Engineering. At the end of the second year, he or she must pass qualifying examinations requiring general radiological science preparation and covering the student's specialty area, prior to the initiation of doctoral research in the third year. The student should be able to complete the doctoral research in two to three years and conclude the program with a thesis defense before the Nuclear Engineering departmental faculty.

To be considered for acceptance into the program, students must have completed a bachelor's degree in physical science or engineering. Additional preparation in physics, mathematics, computer science, and biochemistry is highly recommended. The GRE Aptitude Test and one Advanced Test are also recommended.

Students who enter the program with the master's degree must, as a minimum, complete the Radiological Sciences subject requirements during the initial phase of the program, or demonstrate competence in the required subject areas.

On the application form, students applying to the Radiological Sciences Program should list "Nuclear Engineering" in the space for "Department," and "Radiological Sciences" in the space for "Area of research interest." Applications may be obtained from the MIT Office of Admissions, Room 3-103, Cambridge, Massachusetts 02139. The application deadline is January 14. Subsequent acceptance into the program requires an affirmative assessment by the Radiological Sciences Review Committee.

Interested students should contact Dr. Alan C. Nelson, Room E25-330, MIT, Cambridge, Massachusetts 02139, (617) 253-5799.

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.

Stephan Lewis Chorover, Ph.D.

Merrill Frederick Garrett, Ph.D.

Ann Martin Graybiel, Ph.D.

Alan Hein, Ph.D.

Richard Held, Ph.D.

Nelson Yuan-Sheng Kiang, Ph.D.
Eaton-Peabody Professor of Communication Sciences

Daniel Nathan Osherson, Ph.D.
(On leave, spring)

Tomaso Armando Poggio, Ph.D.

Mary Crawford Potter, Ph.D.
Chair of the Faculty

Whitman Albin Richards, Ph.D.

Peter Harkai Schiller, Ph.D.
Dorothy W. Poitras Professor in Medical Engineering and Medical Physics

Gerald Edward Schneider, Ph.D.

Richard Jay Wurtman, M.D.
Director, Clinical Research Center

Associate Professors

Suzanne Hammond Corkin, Ph.D.

John Hollerbach, Ph.D.

Ronald Davies Graham McKay, Ph.D.
Edward J. Poitras Associate Professor in Human Biology and Experimental Medicine

Steven Pinker, Ph.D.

William G. Quinn, Ph.D.

Mriganka Sur, Ph.D.

Shimon Ullman, Ph.D.

Assistant Professors

Jeremy Michael Wolfe, Ph.D.

Ellen C. Hildreth, Ph.D.

Adjunct Professor

Edward E. Smith, Ph.D.

Visiting Scholars/Scientists

Heinrich H. Bulthoff, Ph.D.
Samuel A. Ellias, M.D., Ph.D.
Frank Thorn, O.D., Ph.D.

Technical Instructors

Henry Hall, S.B.
Diane Major

Principal Research Scientist

Joseph Aloysius Bauer, Jr., M.S.

Research Associates/Engineers/Scientists

Indiran Amarasingham, M.S.E.E.
Rae Ann Clegg, B.A.
Benjamin Morgan Dawson, Ph.D.
Allan F. Doyle, S.B.
Rhea Diamond Gendzier, Ph.D.
Jane Gwiazda, Ph.D.
Sonal Jhaveri, Ph.D.
Christof Koch, Ph.D.
Harris R. Lieberman, Ph.D.
T. John Rosen, Ph.D.
Janet C. Sherman, Ph.D.
Steven Wertheim, Ph.D.

Research Affiliate

William Abend, M.D.

Postdoctoral Associates/Fellows

Samuel Cartinhour, Ph.D.
Alice Cronin-Golomb, Ph.D.
Elisabeth Folkers, Ph.D.
Simon Giszter, Ph.D.
Norberto Grzywacz, Ph.D.
James Hodgson, Ph.D.
Juan Jimenez-Castellanos, M.D.
Nikolaos Logothetis, Ph.D.
J. Riley McCarten, M.D.
Susan Mickel, M.D.
Theodore E. Milner, Ph.D.
Wendi Neckameyer, Ph.D.
Helen Newman-Gage, Ph.D.
Barbara Ranscht, Ph.D.
Bernhard A. Sabel, Ph.D.
Janell Schweickert, Ph.D.
Randall Smith, Ph.D.
Alessandro Verri, Ph.D.

Administrative Officer

Vera Ballard, B.A., C.S.S.

Administrator for Academic Programs

Janice Ellertsen Nagle

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 biological intelligence. To this end, the department is focusing on three themes: neuroscience, computation, and cognition.

In the area of neuroscience, investigators are using a number of new approaches ranging from molecular biology to biophysics, genetics, and electrophysiology. The application of these techniques is leading to exciting findings about the nervous system that provide a new understanding of fundamental mechanisms of brain function. In turn, these insights have the profound clinical implication of generating a framework for the treatment of neurological and psychiatric disorders.

The computation approach is an interdisciplinary combination of the experimental technologies of neuroscience with the theoretical power coming from the field of artificial intelligence. This approach is providing new intellectual thrust in a number of areas in the neural and cognitive sciences including vision and motor control.

In the area of cognition, 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 is also leading to applications in education, artificial intelligence, human-machine interaction, and the treatment of cognitive and language disorders.

Research activities are carried on in the department's laboratories in close collaboration with the teaching programs. Research in neurobiology focuses on the development of neural connectivity, the molecular basis of behavior in simple neural circuits, and neurochemistry. In the area of systems neuroscience, the main concern is with vision and motor systems, where the scientific aims 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. Perception research attempts to understand the encoding of color, lightness, form, and depth information by the visual system and the development of these processes in infants. In 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 all areas of research covered by the Department, the study of neurologically impaired patients is an important source of additional data.

Department facilities include equipment for studies ranging from molecular neurobiology to electrophysiology, neurotransmitters, psychophysics, human information processing, and linguistics. The Department maintains a machine shop, an electronic shop, and a specialized library. The multi-user laboratory of the Center for Cognitive Science provides computational facilities for real-time experimental control, data analysis, modeling, and linguistic analysis, and is a major resource for research activities on human information processing and psycholinguistics. Students and faculty also may use the facilities of other MIT departments and may occupy office and laboratory space in interdepartmental centers such as the Artificial Intelligence Laboratory, the Center for Cognitive Science, and the Clinical Research Center.

Undergraduate Offerings

Subjects at the undergraduate level normally begin with 9.00 Introduction to Psychology, 9.62J Introduction to Cognitive Science, or 9.90 Human Development: Individual and Social Perspectives. 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.

Bachelor of Science in Cognitive Science Course IX

Cognitive science is an evolving field of study concerned with the psychology of human intellect. 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 relevant parts of 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: 75-84

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 or 18.063

Four of the following six subjects:
24.900J The Study of Language, 9
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.

Units in Departmental Program that also satisfy the General Institute Requirements (27-33)

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 also 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
The 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: 72-81

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 or 18.063

Four of the following six subjects:
24.900J The Study of Language, 9
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 also listed in the subject description.

Graduate Study

The Department offers programs of study leading to graduate degrees in Brain Sciences and Cognitive Sciences. 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. Course work for the degree in **Brain Science** is intended to reflect both the unity and diversity of this area. All students will take an intensive course in the essentials — from molecular and cellular features of neurons, through physiology and anatomy, to 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 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 specific research interests of the student. Course work for students in **Computational Neuroscience** is intended to give both a practical understanding of how the vertebrate brain is organized and a theoretical background for dealing with computational aspects of biological information processing.

Candidates for a degree in **Cognitive Sciences** take an intensive survey course in cognition, core courses in topics such as language processing, language acquisition, cognitive development, perception, natural computation, and visual information processing, and additional courses outside the Department that are relevant to the student's program of research (linguistics, philosophy, logic, mathematics, or computer sciences). Competence in statistics is also required. The focus of the training program, however, is on faculty-supervised research, which students begin during their first year and continue throughout their graduate careers.

By the end of their first year, students select a research advisor on the faculty and arrange for a program of individual research on a topic of mutual interest. After the general examinations, the principal activity of the student will be in carrying out independent research, acquiring proficiency by hands-on experience and by individual discussions with the research advisor. 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, and a limited number of fellowships, subject to availability of funds.

Inquiries

Additional information regarding teaching and research programs in the department, admissions, assistantships, and financial aid, may be obtained from Jan Nagle, Department of Brain and Cognitive Sciences, Room E25-406, MIT, Cambridge, Massachusetts 02139, (617) 253-5741.

Additional Programs

Harvard-MIT Division of Health Sciences and Technology

(HST)

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 actively engaged in education, research, and development.

The Division offers two educational programs: a curriculum in Biomedical Sciences leading to the M.D. degree, and a curriculum in Biomedical Engineering and Physical Sciences leading to the Ph.D. degree.

The educational program in **Biomedical Sciences** is oriented toward students with a strong interest and background in quantitative science, especially in the biological, physical, engineering, and chemical sciences. The subjects in human biology developed for this curriculum represent the joint efforts of life scientists, physicians, physical scientists, and engineers selected from the faculties of both universities. The 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. 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. Prior to graduation, 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. Exceptionally well qualified undergraduates at Harvard, Radcliffe, and MIT may apply to the Division for admission after their junior year. Students considering such action should consult with the Directors of the Division for guidance.

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 **Biomedical Engineering and Physical Sciences** 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 M.D. candidates[2]; 3) specialized clinical training, which is designed to equip the student in 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.

Faculty

There are over 200 faculty members from both MIT and Harvard Medical School associated with the Division.

Further information about the Division, including 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 the interdepartmental study 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 010, HST 030, HST 090, HST 100, HST 110, and HST 130J.

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 which have produced the present composition of sea water and sediments. Principal research areas include water column geochemistry, sedimentary geochemistry, seawater-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

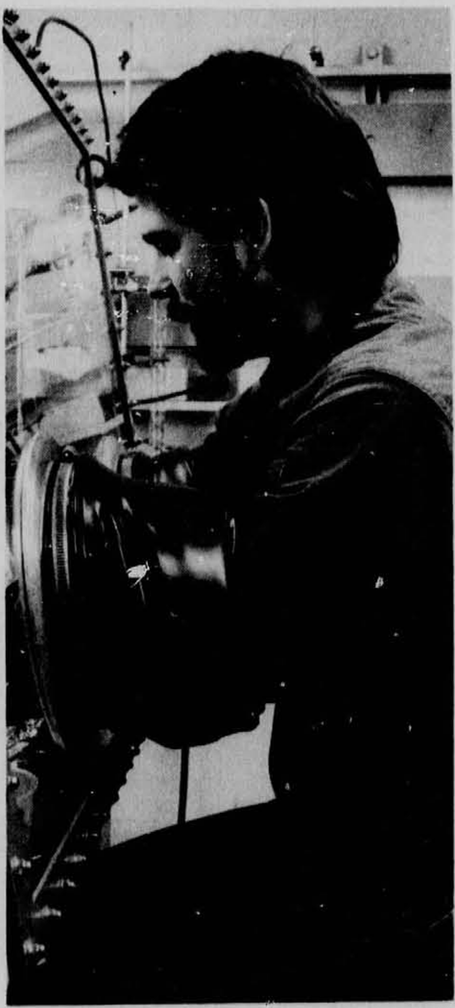
Biological oceanography seeks to describe the biological processes which are active in the marine and bordering environments. The research of biological oceanographers is diverse, ranging from ecology and systematics to biochemistry and physiology. The programs in biological oceanography are coordinated by the Department of Biology and WHOI, and may involve research in other MIT departments such as Applied Biological Sciences and Civil Engineering. The programs lead to the Doctor of Science or Doctor of Philosophy.

Oceanographic Engineering

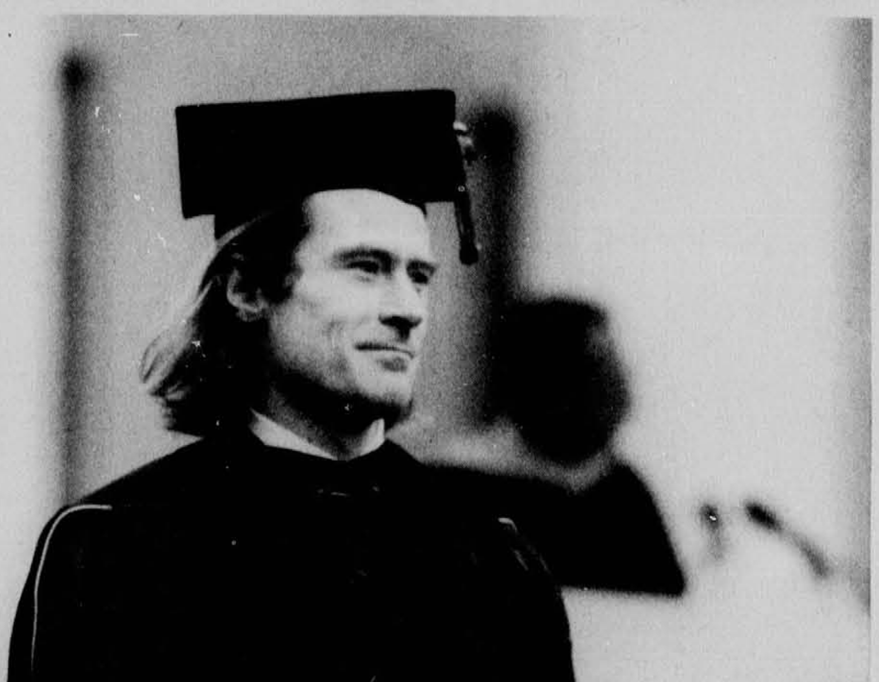
Oceanographic engineering involves the application of physics and the engineering sciences to the study of oceanic processes and the design of instruments, systems, and structures required to observe, measure, and work in the ocean. The Departments of Chemical Engineering, Civil Engineering, Electrical 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.


Description of Subjects



Explanatory Notes

The subject descriptions given in this chapter are subject to change. The final list of subjects to be given in 1986-87 will be published with the class schedules booklet prior to the beginning of each term.

The information given below the **number and name of the subject** is as follows:

The number(s) of **prerequisite subjects,** if any. Numbers in italics indicate subjects which 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; "G" is a subject given primarily for graduate students. 1, 2, J, and S represent fall, spring, January, and summer terms, respectively.

SD or LAB or HUM-D indicates that the subject is on the approved list for Science Distribution, Laboratory, or Humanities Distribution credit.

HASS indicates subjects outside the School of Humanities and Social Science which can be used to satisfy the Humanities, Arts, and Social Sciences Requirement (other than HUM-D subjects).

The **year offered** comment states "Next offered 1987-88," or "Not to be offered 1987-88." There is no comment if it is offered both 1986-87 and 1987-88.

The **time distribution of the subject,** showing in sequence the units allotted to: recitation and lecture; laboratory, design, or field work; and preparation. Each unit represents 14 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, when 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 the subject is offered jointly by more than one department. The subject numbers of the other departments are indicated (Same subject as ———J).

(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
Applied Biological Sciences	20
Biology	7
Chemistry	5
Earth, Atmospheric, and Planetary Sciences	12
Mathematics	18
Physics	8
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

1 Civil Engineering

Fundamentals

1.UR Research in Civil Engineering

Prereq.: —
U (1, 2)
Arr.

Individual research or laboratory study under faculty supervision. Also, opportunities in ongoing research program. Limited number of funded traineeships available.
R. V. D. Whitman

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. Emphasis on modular, structured code. Extensive use of computer-based problem sets in Pascal (or C in some semesters) includes: numerical analysis, evaluation of algorithms, graphics, data structures, searching, sorting, matrix methods, and simulation.
E. Kausel, J. H. Slater, N. H. Wilson

1.01J Engineering Aspects of Economic Analysis

(Same as 14.014J)
Prereq.: —
U (1) HASS
4-0-8

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 R. V. D. Whitman.

1.02 Optimization Theory and Engineering Application
(Revised Unit)

Prereq.: 1.00
U (1) **Next Offered 1987-88**
3-0-9

Introduction to mathematical programming. A review of unconstrained and constrained programming including Kuhn-Tucker conditions and convexity. The role and use of Lagrangian and duality theory, linear programs and the simplex method, network models, integer and dynamic programming models. Examples and case studies taken from engineering problems. Students are expected to program various optimization algorithms.
Y. Sheffi

1.03 Introduction to Probability and Statistics for Engineers
(Revised Unit)

Prereq.: 1.02, *18.03*
U (2)
3-0-9

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.
G. B. Baecher

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.
R. V. D. Whitman

1.05 Behavior of Physical Systems II

Prereq.: 1.04, *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 Stochastic Models, Reliability, and Simulation of Large-Scale Systems
(New)

Prereq.: 1.00, 1.03
U (1) **Next Offered 1987-88**
3-0-9

Applications of stochastic processes, reliability theory, and Monte Carlo simulation to the design and analysis of large-scale engineering systems and networks. Example-motivated coverage of: binomial, Poisson, and discrete- and continuous-time Markov processes; birth-and-death models and introductory queueing theory; reliability of serial and parallel systems; fault-tree analysis; computer generation of random variates, simulation languages and statistical reliability of simulation results.
A. R. Odoni

1.07 Engineering Applications of Artificial Intelligence
(New)

Prereq.: 1.00
U (1) **Next Offered 1987-88**
3-0-9

The role of knowledge engineering, expert systems, and specialized data structures in engineering analysis and design. Covers the underlying theory and requires students to build simple expert systems.
D. Sriram

1.08 Design of Automated and Robotic Systems

Prereq.: —
U (1) **Next Offered 1987-88**
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, program, and assemble simple systems.
A. Slocum

For additional undergraduate introductory subjects, see: 1.20, 1.30, 1.40, 1.50, 1.60, 1.70, 1.80.

Undergraduate Laboratory Subjects

1.101 Decision Analysis Laboratory (Revised Unit)

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 used to reduce and plot data and test theoretical hypotheses. The implications for decision analysis and engineering design 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; 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.
L. J. Gibson

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, O_2, 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)

Prereq.: 18.03
G (1)
3-0-6

Survey of numerical methods for ordinary and partial differential equations. Emphasis on finite difference and weighted residual methods. Includes review of linear algebra; direct and iterative matrix solutions; finite difference approximations; consistency, stability, and convergence; Fourier analysis; finite element methods. Examines both steady and transient equation describing physical systems of interest. Development of computer programs is emphasized.
M. A. Celia

1.122 Finite Element and Boundary Element Methods (A)

Prereq.: 1.51
G (2)
3-0-6

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.

For additional related subjects, see: 1.204J, 1.368, 1.70.

Analytical Mechanics

1.13 Design for Construction Automation (New)

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 encouraged to design, build, and test model and fullscale systems.
A. Slocum

1.131 Analytical Methods in Physical Systems

Prereq.: 18.03
G (1)
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. Fourier series. 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. 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. Alternate years.
V. C. Li

1.133 Geomechanics (A)

Prereq.: 1.572
G (1)
3-0-6

Nonlinear constitutive laws and field equations for porous media. Dynamic soil-structure interaction. Dynamic amplification in soil deposits. Wave passage and seismic environment. Hysteresis and correspondence principle. Dynamics of foundations and pile groups. Transmitting boundaries and infinite elements. Computational techniques and applications to certain constructed facilities such as nuclear power plants, buried structures, pipelines, tall buildings, bridges.
E. Kausel

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: G. B. Baecher.

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

1.143J Mathematical Optimization Techniques (A)

(Same subject as 13.622J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 13.622J.
D. H. Marks, H. N. Psaraftis

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

1.147J Applied Microeconomic Analysis (A)

(Same subject as 14.110J)
Prereq.: 14.01 or 1.01J
G (1) **Next Offered 1987-88**
3-0-6

See description under subject 14.110J.
W. C. Wheaton

1.148J Economics of Project Evaluation (A)

(Same subject as 14.111J)
Prereq.: 14.03 or 14.120
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, estimation and reporting to four case studies. Data collection in both real world and laboratory settings.
S. McNeil

For additional related subjects see: 1.202J, 1.203J, 1.207, 1.281, 1.283J, 1.44, 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.: Permission of Instructor
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.
E. H. Vanmarcke, D. Veneziano

1.152 Risk Assessment in Engineering II (A)

Prereq.: 1.151
G (2)
3-0-6

Advanced probabilistic modeling and statistical analysis for engineering systems. Part 1: Second-moment characterization of random vectors, sequences, functions, and fields. Time and frequency domain analysis. Linear filtering and random vibration, Gaussian, Poisson, and Markov models. Extremes of random functions. Digital simulation. Part 2: Estimation of covariance observations. Models for decision-making: Poisson and Markov processes with reward.
D. Veneziano, E. H. Vanmarcke

1.155 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

1.158 Introduction to Queuing Theory (A)

Prereq.: Permission of Instructor
G (1)
1-0-2

A specialized mini-subject offered in the last third of the term. Topics: Fundamental concepts of queuing theory; Markovian, semi-Markovian, and non-Markovian queues; priority queues; queuing networks. Selected applications. Instructor should be contacted for information about starting date.
A. R. Odoni

For additional related subjects, see: 1.203J, 1.34, 1.44, 1.581, 1.711, 1.712, 1.732.

Institutions and Public Policy

1.165 Introduction to Technology and Law

Prereq.: —
U (1)
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

1.20 Transportation Systems Analysis

Prereq.: 1.03
U (1)
4-0-8

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, logistics analysis, and location theory. Analyzes transportation networks including prediction of flow patterns and service quality. Evaluates impacts and design of transportation services and facilities. Additional recitation section required for undergraduates to cover selected topics in more detail.
J. Sussman, M. E. Ben-Akiva

1.202J Demand Modeling (A) (Revised Content and Unit)

(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, multiprobabilistic 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.
M. E. Ben-Akiva

1.203J Logistical and Transportation Planning Methods (A)

(Same subject as 6.281J, 11.526J, 13.665J, 15.078J, 16.76J, TPP 43J)
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, pick up 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. Discussion of implementation difficulties.
A. I. Barnett, R. C. Larson, A. R. Odoni, H. N. Psaraftis

1.204 Computer Algorithms in Transportation (A)

Prereq.: 1.00 or 16.008; 1.02
G (2)
3-0-6

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 minicomputer assignments.
Y. Sheffi

1.205 Advanced Transportation Demand Modeling (A)

Prereq.: 1.202J or CTS I50J
G (1)
3-0-6

Theories and applications of travel and mobility behavior models. Includes: structure of multidimensional probabilistic choice models, statistical estimation techniques with multiple data sources, model transferability, estimation and forecasting with very large choice sets, dynamical models. Issues in model specification, including use of stated preference data, treatment of intra-household interactions and complex travel patterns. Term paper required.
M. E. Ben-Akiva

1.207 Transportation Networks Equilibrium Analysis (A)

Prereq.: 1.02, 1.03
G (1) **Next Offered 1987-88**
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

1.208 Transportation and Logistics Analysis (A) (New)

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.
S. C. Graves, Y. Sheffi

1.21 Transportation Infrastructure (Revised Unit)

Prereq.: 1.01J or 14.01; 1.03; 1.04
U (1) **Next offered 1987-88**
3-3-6

Presents a critical analysis of the current status of US transportation infrastructure, encompassing highways, railways, transit, waterways, and airports. Develops engineering concepts for lifecycle analyses of facilities, defining performance, serviceability, maintenance policy, reliability, and costs, and allowing hands-on use of related models. Also treats economic, financial, management, and technological issues surrounding facility construction, maintenance, rehabilitation, and operation.
M. J. Markow, S. McNeil

1.214 Public Transportation

Prereq.: 1.20
U (2)
4-0-8

See description under subject 1.258.
N. H. M. Wilson

1.22 Transportation Infrastructure Systems (A) (New)

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 its use. Emphasis on a systems approach using computer models. A transportation management computer simulation game used to demonstrate the complex interactions in managing transportation infrastructure.
S. McNeil

1.231J Planning and Design of Airport Systems (A)

(Same subject as 16.781J)
Prereq.: Permission of Instructor
G (2)
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.
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) (Revised Unit)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
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 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, M. J. Markow

1.252J Urban Transportation Planning (A)

(Same subject as 11.380J)
Prereq.: —
G (2)
3-0-6

Development of urban transportation planning over the past two decades. Movement of the transportation policy perspective from limited interpretations to multi-objective planning, and from an emphasis on large-scale facility planning toward an increased reliance on small-scale, traffic management techniques. Discusses in detail the methodological change that has accompanied the evolution in transportation planning. Also presents promising theories for understanding institutional relations and change.
R. A. Gakenheimer

1.254J Infrastructure in Third-World Countries (A) (New)

(Same subject as 11.469J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under 11.469J.
R. A. Gakenheimer, J. Tendler

1.255J Politics, Growth, and Development in the Middle East (A) (New)

(Same subject as 17.558J)
Prereq.:
G (1)
3-0-9

See description under subject 17.558J
N. Choucri, P. Khoury, F. Moavenzadeh, D. Lessar

1.256J Technology, Business, and Public Policy in the Middle East (A) (New)

(Same subject as 17.560J)
Prereq.: —
G (2)
3-0-9

See description under subject 17.560J
N. Choucri, A. Adelman, F. Moavenzadeh D. Lessard

1.258 Public Transportation Service and Operations Planning (A)

Prereq.: 1.201J
G (2)
3-0-6

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 a proposed service change. Additional recitation section required for undergraduates to cover selected topics in more detail.
N. H. M. Wilson

1.259 Transit Management (A)

Prereq.: 1.258
G (1)
3-0-6

Management methods of relevance to public transportation systems. Topics: strategic planning management; labor relations; maintenance planning and administration; financial planning; marketing; and management information and decision support systems. Shows how these general management tasks are dealt with in the transit industry and presents alternative strategies. Identifies alternative arrangements for service provision, including different ways of involving the private sector in public transportation.
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: N. H. M. Wilson.

1.271 Research Seminar in Transportation

Prereq.: Permission of Instructor
G (2)
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.
M. E. Ben-Akiva

1.281 Transportation Economics (A)

Prereq.: 14.01 or 1.01J
G (1)
3-0-6

Theory and behavior of large transportation systems: 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.
D. Pickrell, G. McCullough

1.283J Urban Economic Analysis (Revised Content)

(Same subject as 11.410J, 14.573J)
Prereq.: 14.03 or 14.04
G (1)
3-0-9

See description under subject 11.410J.
W. C. Wheaton

1.286 Freight Transportation Management (A)

Prereq.: 1.201J
G (2)
3-0-6

Analytical methods for freight systems emphasizing applications to shippers, rail and truck carriers. Logistics and inventory theory focusing on choice of carrier, routing, and facility location. Performance and cost models of terminals and line-haul operation for rail and truck. Integration of shipper and carrier perspectives in system models. Reviews regulatory, pricing, labor, and other issues facing the industry. Additional recitation section required for undergraduates to cover selected topics in more detail.
G. A. Kocur, Y. Sheffi

1.298 Research in Transportation

Prereq.: —
G (1, 2, S)
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)
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.
G. B. Baecher

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.
G. B. Baecher, H. H. Einstein

1.322 Soil Behavior (A) (Revised Unit)

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.: 1.30
G (2)
3-0-6

Applies theory of wave propagation and dynamics of lumped systems to problems in soil dynamics. Stress-strain behavior during transient and repeated loadings; relation to wave velocity. Analysis of machine foundations; effect of soils upon seismic motions; earth dams and retaining walls during earthquakes; soil-structure interaction; other selected applications.
R. V. D. Whitman

1.34 Reliability in Geotechnical Engineering (A)

Prereq.: 1.151, 1.30
G (2)
Arr.

Quantitative treatment of uncertainty in soil properties and the performance of geotechnical facilities. Probabilistic description of loadings and environmental conditions affecting soil behavior. Reliability analysis of soil structures. Statistical analysis of field and laboratory data. Treatment of risk and uncertainty in decision situations involving soil exploration, design, and performance monitoring.
D. Veneziano, G. B. Baecher

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.
M. M. Baligh

1.361 Advanced Soil Mechanics and Engineering (A)

Prereq.: 1.30
G (1)
3-0-6

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
G (2)
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.
M. M. Baligh

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

1.368 Computer-aided Analysis in Geotechnical Engineering (A)

Prereq.: 1.351
G (2)
3-0-6

Use of computers in the analysis of geotechnical problems: steady and transient flow in porous media, stability of embankments and slopes, retaining structures, pile driving, excavations and tunneling. For each area, the necessary theoretical background reviewed and discrete modeling methods as implemented in computer programs discussed and applied to selected problems. Extensive use of digital computers. Working knowledge of FORTRAN expected.
A. S. Azzouz

1.37 Geotechnical Measurements and Exploration (A)

Prereq.: 1.30
G (1)
2-4-3

Students perform a variety of laboratory experiments illustrating fundamental aspects of soil behavior including classification, index, and engineering properties. Emphasizes measurement of load-deformation characteristics under several different boundary conditions. Exposure to special devices, geotechnical exploration, field investigation, and *in situ* testing. Experiments involve data reduction, evaluation, and presentation of results.
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 1987-88**
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 1987-88**
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

1.384J Introduction to Mining and Mineral Technology

(Same subject as 3.095J, 12.043J)
Prereq.: —
U (1)
3-0-6

See description under subject 3.095J.
H. H. Einstein, R. G. Burns, J. F. Elliott, C. R. Peterson

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: G. B. Baecher.

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.
R. D. Logcher

1.411J Building Construction I

(Same subject as 4.402J)
Prereq.: —
U (1)
4-0-8

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 (2)
2-4-3

See description under subject 4.403J.
Staff

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, H. G. Irwig

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)

Prereq.: —
G (1)
3-0-6

First of two-semester sequence on computer techniques and systems for control of design and construction projects. Relationship of project breakdown to estimating, budgeting, and financial control. Use of network-based systems for planning and time control of projects, including CPM and PERT and resource-constrained scheduling. Database design concepts for decision support systems. Integrating control of costs and time, with cash flow and manpower projections, with comparison of potential to current practice. Requires background in accounting principles.
R. D. Logcher

1.433 Project Control II (A) (New)

Prereq.: 1.432
G (2)
3-0-6

Continuation of 1.432. Control of design firms and owner construction programs. Estimating methods and systems. Database design for control systems. Applications generators and system design techniques applied in term project creating a tailored control system.
R. D. Logcher

1.44 Analysis Methods in Infrastructure Renewal (A)

Prereq.: —
G (2)
3-0-6

A focus on mathematical modeling for infrastructure renewal. Analysis of cause and effect. Performance estimation and standards. Simulation and optimization of maintenance systems. Risk analysis and management. Scheduling and prioritizing investments. Inspection strategies and signal processing from automated analysis tools. Operational strategies for existing systems. Emphasis on computer-based modeling and case studies.
D. H. Marks, M. J. Markow

1.45 Construction Finance (A)

Prereq.: —
G (2)
3-0-6

Examines financing methods 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 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) (New)

Prereq.: —
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)
2-0-1

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.
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.
D. H. Marks

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.
J. H. Slater

1.51 Mechanics of Construction Materials

Prereq.: 1.04
U (1)
4-0-8

Mechanical behavior of materials used in structural and geotechnical engineering, with emphasis on steel and concrete. Problem formulation in mechanics of solids. Elasticity, energy methods, and principle of virtual work. Elementary plasticity, plastic yielding under combined stresses, and limit analysis. Torsion, plane stress, and plane strain. Stress concentrations. Study of failure mechanisms, brittle fracture and fatigue; influence of composition on mechanical properties of concrete. Lectures supplemented by computer-aided learning software.
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, with emphasis on concrete, examined. 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

Students explore the concepts, techniques, and devices used to measure engineering properties of materials. Several of these devices are used to measure properties of common construction materials. These same materials are then used to construct simple systems which illustrate and test the performance concepts and hypotheses taught in basic mechanics subjects.
J. T. Germaine

1.541 Behavior of Concrete Structures (A)

Prereq.: 1.52
G (1)
3-0-6

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)

Prereq.: 1.51
G (2)
3-0-6

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)
2-0-4

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 Control in Engineering Structures (A)

Prereq.: 1.51
G (1) **Next Offered 1987-88**
3-0-6

Application of fracture mechanics concepts to control fracture and fatigue behavior in engineering structures. Effect of material, temperature, loading rates, and plate thickness on fracture resistance parameters, and determination in the laboratory. Fracture control design. Fatigue crack initiation and propagation under cyclic loads. Fracture control plans. Case histories of structural fracture failure. Current research directions, especially in fracture processes in fiber-reinforced concrete.
V. C. Li

1.551J Analysis and Design of Offshore Structures (A)

(Same subject as 13.112J)
Prereq.: 1.51 or 13.10J
G (1)
4-0-8

Fundamental concepts in analysis and design of fixed offshore platforms. Design philosophies and criteria. Specification of environmental design criteria and computation of design loads; in-depth treatment of wave theories, wave statistics and hydrodynamic loads. Construction materials and their behavior in the marine environment. Preliminary and detailed structural and foundation design procedures. Deterministic and stochastic dynamic analysis. Design for fatigue and seismic effects. Reliability analysis procedures.
S. Shyam Sunder, J. K. Vandiver

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

1.571 Advanced Structural Analysis (A)

Prereq.: 1.51
G (1)
3-0-6

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 Structural Dynamics (A)

Prereq.: 1.121, 1.51
G (1)
3-0-6

Analysis of structures subjected to dynamic loads. Theory developed for single degree of freedom system and generalized to multiple degree of freedom and continuous systems. Analytical and numerical techniques for solution of equations of motion. Transient, steady-state, and modal response. Applications to earthquake loads, forced vibrations, and presentation of approximate (practical) methods.
E. Kausel

1.581 Structural Reliability (A)

Prereq.: 1.151
G (2)
3-0-6

Analysis and design specification of structural performance and safety through probability theory. Description of common structural loads (seismic, wind, tornado, snow, occupancy, vehicles). Procedures for data analysis and probabilistic modeling. Variability of material properties. Structural system reliability, statics, and dynamics. Bases for modern structural code specifications and for design procedures used in more advanced practice. Optimum design accounting for uncertainty and failure consequences.
D. Veneziano

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.
G. B. Baecher

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: G. B. Baecher.

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, fracture, fatigue, and durability behavior. Applications to traditional construction materials (steel, concrete, and timber) as well as recent developments in civil engineering materials (composites, ice mechanics, fabric materials for geotextiles and inflatable dome structures).
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)
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: G. B. Baecher.

1.599 Teaching in Constructed Facilities

Prereq.: —
G (1, 2)
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: G. B. Baecher.

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 1987-88**
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)

Prereq.: 1.63
G (2)
3-0-6

Advanced treatment of stratified-fluid dynamics, emphasizing the basic phenomena that influence environmental flows. Linear and nonlinear internal waves in multiple layer and continuously stratified fluids. Thermal and double-diffusive convection, dynamics of intrusions and selective withdrawal. Boundary layers, stability and onset of turbulence. Introduction to turbulence modeling and the dispersion of heat and pollutants. Two-phase flows. Alternate years.
W. K. Melville

1.65 Experimental Methods in Hydrodynamics (A)
(New)

Prereq.: 1.60
G (2) **Next offered 1987-88**
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, electro-mechanical, and flow visualization. Emphasis on laboratory techniques, but some examples 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 1987-88**
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 Natural Water Bodies (A)

Prereq.: 1.63
G (1)
3-0-6

Treats the principal physical processes in natural water bodies. Emphasizes the molecular and turbulent vertical transport of mass, momentum, heat, and mechanical energy. Includes: physical properties of air and water; governing conservation equations in exact and approximate form; meteorological forcing;

fluxes across the water surface; mixed layer dynamics and stratification; bottom boundary conditions; hydrologic, tidal, wind, and density driven circulations; 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, cnoidal waves, wave breaking. Emphasizes physical interpretation of mathematical results and their engineering application. Storm surges, 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)

Prereq.: 1.69, 1.131
G (2)
3-0-6

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. Nonlinear waves in shallow water. Solitons and harmonic generation. Nonlinear resonances on a beach or in a bay. Alternate years.
C. C. Mei

1.692 Wave Dynamics in Oceanographic Engineering (A)

Prereq.: 1.69, 1.131
G (2) **Next offered 1987-88**
3-0-6

Problems in waves and currents of interest to oceanographic engineers. 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. Wave effects on a porous elastic sea bed. Alternate years.
C. C. Mei

1.695J Principles and Physics of Remote Sensing (A) (New)

(Same subject as 12.975J)
Prereq.:—
G (1)
3-0-6

See Description under subject 12.975J.
(Woods Hole Staff): J. S. Jaffe, K. A. Kelly

1.696J Application of Remote Sensing and Image Processing (A) (New)

(Same subject as 12.976J)
Prereq.:—
G (2)
3-3-3

See description under subject 12.976J.
(Woods Hole Staff): J. S. Jaffe, 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 analytical 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 select/develop models, run simulations and interpret results in written and oral reports. For advanced undergraduates or graduate students wishing exposure to broad applications. Some programming experience assumed.
E. E. Adams, F. E. Perkins

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 Dynamic Hydrology (A)

Prereq.: 1.03, 1.60, 1.71
G (2)
3-0-6

Topics in theoretical hydrology: precipitation processes. Snow physics. Soil physics and soil moisture movement. Water use by vegetation. Kinematic wave approximation to hydrograph formation. Flood routing. Interaction of geomorphology and basin response. Analysis of extreme events. Physically based derived distributions of flood peaks and volumes. Alternate years.
P. S. Eagleson

1.712 Sampling, Synthesis, and Forecasting of Hydrologic Processes (A)

Prereq.: 18.444 or equivalent
G (2)
3-0-6

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

1.713 Hydroclimatology (A)

Prereq.: 1.03, 1.60, 1.71
G (2) **Next offered 1987-88**
3-0-6

Emphasis on modeling the one-dimensional long-term water and heat balances for mesoscale landsurfaces: Global scale environmental problems. Energy balance of the earth. General circulation of atmosphere and oceans. Structure of the hydrothermal coupling in hydrology and its modeling at large scale. Parameterization of soil and vegetation. Emphasizes the dynamic interaction of climate, soil, and vegetation with examples from observations. Principles and utility of remote sensing in mesoscale hydrology. Alternate years.
P. S. Eagleson

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) **Next offered 1987-88**
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)
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.
H. F. Hemond

1.724 Groundwater Modeling (A)

Prereq.: 1.72
G (2)
3-0-6

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 on mathematical derivations of governing equations. Students develop computer codes for various physical systems of interest. Familiarity with basic numerical methods is assumed.
M. A. Celia

1.731 Optimization Methods for Water Resource Management (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, capacity expansion, conjunctive use of surface and groundwater, and reservoir operations.
D. McLaughlin

1.732 Probabilistic Methods for Water Resource Management (A)

Prereq.: Background in Probability Theory
G (1)
3-0-6

Effects of uncertainty on water resource management. Spatial and temporal variability. Quantitative methods for describing and analyzing uncertainty. Incorporating uncertainty into models and decision making. Case studies include reservoir operations, groundwater resource development, water quality monitoring. Knowledge of optimization concepts and random processes desirable.
D. McLaughlin

Water Quality Control and Environmental Management

1.75 Limnology and Wetland Ecology (A)

Prereq.: Permission of Instructor
G (2)
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)
3-0-6

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 Plankton 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, and primary production in lakes and oceans. Includes photosynthesis, nutrient limitation and uptake kinetics, element cycles, population growth, phytoplankton/zooplankton interactions and secondary production. Lecture/seminar format with extensive outside readings.
S. W. Chisholm

1.80 Fundamentals of Ecology

Prereq.: —
U (2)
3-1-8

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; population growth; and physiological ecology. Emphasis on aquatic systems.
S. W. Chisholm

1.811J Environmental Law: Pollution Control (A)

(Same subject as TPP 33J)
Prereq.: Permission of Instructor
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

(Same subject as TPP 34J)
Prereq.: 1.811J, 3.575J or 10.805J
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)
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 Organic Compounds in Aquatic Environments (A)

Prereq.: 5.41 or 5.12
G (1)
60-6

After an introduction to the cycling of natural organic matter in aquatic environments discussions focus on the sources and fates of anthropogenic organic compounds. Uses physical chemical properties to predict chemical transfers between environmental compartments (air, water sediments, biota). Uses empirical approaches to estimate chemical and biochemical transformations. Ultimately develops models to assess the environmental concentrations (and related biological exposures) of hazardous organic compounds introduced into water resources.
P. M. Gschwend

1.84 Aquatic Particles (A) (New)

Prereq.: Permission of Instructor
G (1)
3-0-6

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

1.85 Wastewater Treatment Engineering (Revised Content and Unit)

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)
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)
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)
0-6-0

1.92 Advanced Civil Engineering Internship

Prereq.: 1.91
G (1, 2, S)
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.
O. Buyukozturk

1.961-1.965 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.
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.
O. S. Madsen

1.980J Engineering Policy Thesis Seminar (A)

(Same subject as 16.783J, TPP 13J)
Prereq.: Thesis Registration
G (1, 2)
2-0-1

See description under subject TPP 13J.
R. de Neufville, A. R. Odoni

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.
R. V. D. Whitman

1.999 Undergraduate Studies in Civil Engineering

Prereq.: —
U (1, 2, S)
Arr.

Individual study, research, or laboratory investigations under faculty supervision.
R. V. D. Whitman

2 Mechanical Engineering

2.UR Undergraduate Research in Mechanical Engineering

Prereq.: —
U (1, 2, S)
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 deformations of rods, shafts, beams, and other simple structures of engineering importance. Emphasizes computer methods and matrix structural analysis.
T. G. Gutowski, 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

2.023 Dynamic Systems

Prereq.: —
G (S)
3-0-6

Review of system dynamics primarily for incoming graduate students; a shortened version of 2.02. No graduate credit allowed for students in Course II.
D. N. Wormley

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 (2)
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. 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 1987-88**
3-0-9

Analyzes kinematic and dynamic characteristics of planar and spatial mechanisms, including machines and robotics manipulators. Use of vector, complex variable and 4 by 4 matrices methods for kinematic analysis. Systems including flexible and rigid elements and active control systems. A brief introduction to kinematic synthesis methods and use of digital simulations for dynamics. Applications from industrial machine systems and robotic manipulators.
S. Dubowsky

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 (1)
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.
S. H. Crandall, T. R. Akylas

2.063J Sound and Structural Vibration (A)

(Same subject as 13.82J)
Prereq.: 2.03J or 16.004, 13.004, 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

2.065J Flow Noise (A)

(Same subject as 13.84J, 16.082J)
Prereq.: 2.20, 16.02 or 13.021
G (1) **Next offered 1987-88**
3-0-9

See description under subject 13.84J.
P. Leehey, S. E. Widnall

2.071J Introduction to Structural Mechanics (Revised Content and Unit)

(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 Contious Media (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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.: 2.01, 2.31, 2.32
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)
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 basic concepts and special methods in linear elasticity. Reviews fundamentals: stress, strain, tensors, etc. Simple problems: tension, flexure, thick pressure vessels. Torsion of noncircular cross sections. Energy theorems and applications. Planar problems with analytic function theory: holes, cracks, point loads, dislocations. Fundamental three-dimensional problems; contact problems. Introduction to elastic stability. Introduces plate theory.
J. H. Williams, Jr., L. L. Bucciarelli

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 (2)
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) **Next offered 1987-88**
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

2.14 Control System Principles

Prereq.: 2.02
U (1, 2)
3-2-7

Introduces 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)
3-0-9

Modeling of complex linear and nonlinear energetic dynamic engineering systems. Emphasizes subdivision into simple multiport elements and representation by bond graph language. Distributed systems. Field lumping. Analytical and graphical reductions. Efficient digital simulation using the Department computing facilities. Examples including mechanisms, electromechanical transducers, electronic and fluid systems, thermal systems, chemical and biochemical 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 (New)

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)
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, 13.47J, 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, J-J. E. Slotine, M. Athans, G. Stephanopoulos, M. S. Triantafyllou, B. K. Walker

2.155J Multivariable Control Systems II (A)

(Same subject as 6.234J, 10.29J, 13.48J, 16.342J)
Prereq.: 6.233J
G (2)
4-0-8

See description under subject 6.234J.
J. K. Hedrick, J-J. E. Slotine, M. Athans, G. Stephanopoulos, M. S. Triantafyllou, L. Valavani

2.157 Computer-Aided Design (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Use of computers to aid design and manufacturing functions. Geometry: representation of three-dimensional objects, reticular surfaces, Coons' patches, splines. Interactive graphics system components: storage and refresh CRT displays, data tablets, and software. Three-dimensional rotation, translation and perspective transformations, hidden-line removal. Reviews and discusses state-of-the-art CAD systems. Emphasizes development and usage of systems for computer-aided design. FORTRAN proficiency required.
D. C. Gossard

2.161 Computer-Controlled Experimentation (A)

Prereq.: 2.14 or 2.151
G (1)
3-0-9

State-of-the-art techniques involving use of digital and analog computers to monitor and control physical processes. Topics: introductions to analog and digital hardware at the computing module level, programming techniques for digital minicomputers in real-time on-line applications and fundamental topics in signal conditioning and data reduction. Students should be able to program in FORTRAN and to set up elementary simulations on an analog computer.
D. Rowell

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

2.18J Human Factors in Design

(Same subject as 9.39J, 22.088J)
Prereq.: Permission of Instructor
U (2) HASS
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 judgement scaling techniques. Application 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 potential flows. Equations governing viscous fluid flow, and some special solutions. Dimensional analysis and modeling, with application to flow problems. Flows with head losses and gains in ducts and pipes. Boundary layers and separation. Drag and lift.
J. A. Fay

2.21 Fluid Mechanics of Power and Propulsion

Prereq.: 2.20, *2.40*
U (2)
3-0-9

The functioning and design of fluid systems used for energy conversion and propulsion, with emphasis on showing how fundamentals of fluid mechanics may be applied. Analysis of incompressible flow in turbomachines such as pumps and fans; performance characteristics and scaling rules. Introduction to compressible flow theory. Performance of airfoil cascades. Thermo-fluid dynamics of compressible-flow machines, such as gas and steam turbines. Thrust and propulsion efficiency of propellers, turbofans and turbojets, windmills.
M. A. El-Masri

2.22 Computational Methods in Engineering (New)

Prereq.: 18.03, 2.10
U (1)
3-0-9

Computational methods most useful in engineering analysis, including approximation, integration, solution of algebraic, ordinary, and partial differential equations, are introduced. Applications from Heat Transfer, Fluid and Applied Mechanics are discussed, with emphasis on: formulation of physical models, choice of numerical algorithms, error estimates, analysis and interpretation of results, and model validation. Extensive computer homework, knowledge of FORTRAN is expected.
A. Ghoniem

2.25 Advanced Fluid Mechanics (A)

Prereq.: 2.20, *18.075*
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' 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, T. Y. Toong

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; some effects of turbulence. 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. Polymeric liquids and 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)
3-0-9

Momentum transfer in turbomachines. Axial compressors and turbines: design considerations, cascade aerodynamics including effects of viscosity and compressibility, three-dimensional flow, performance limitations; radial machines; hydraulic pumps and turbines; cavitation.
D. G. Wilson

2.277 Biomedical Fluid Mechanics (A)

Prereq.: 2.20
G (2) **Next offered 1987-88**
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
G (1) **Not to be offered 1987-88**
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. High-temperature gas flow in jets, nozzles, hypersonic boundary layers. Chemical effects on turbulence. Engineering applications. Alternate years.
T-Y. Toong

2.282 Combustion (A)

Prereq.: 2.20 or 16.02
G (1) **Next offered 1987-88**
3-0-9

Comprehensive treatment of combustion principles and their applications. Topics emphasized vary from year to year. Fire research. Engine combustion. Combustion instability, linear and nonlinear mechanisms, interactions of acoustic waves with nonuniform and fluctuating reacting flows. Laminar and turbulent flames. Exothermic hypersonic flows. Supersonic combustion. Reacting boundary layers with ablation. Alternate years.
T-Y. Toong

Materials

(See also listing under Polymers and Fibers)

2.30 Mechanical Behavior of Materials (New)

Prereq.: 2.01, *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)

(2.333J)
(Same subject as 3.25J)
Prereq.: 2.31, 2.32 or 2.30 or 2.301
G (2) **Next Offered 1987-88**
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) (New)

(Same subject as 3.26J)
Prereq.: 2.31, 2.32, or 2.30 or 2.301
G (2) **Next Offered 1987-88**
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

2.31 Mechanical Behavior of Materials I

Prereq.: 2.01
U (1)
3-1-5

Introduces mechanical behavior of engineering materials emphasizing a combined materials science and continuum mechanics approach. Major topics: elasticity, rate-independent plasticity, linear elastic fracture mechanics, and fatigue failure. Laboratory experiments involving a variety of materials, testing methods, and analyses, and a special project. Requires competency in 2.01. Recommended that it be taken in term following 2.01.
L. Anand

2.32 Mechanical Behavior of Materials II

Prereq.: 2.31, *2.86*
U (2)
3-1-5

Combined materials science and continuum mechanics treatment of rate-dependent deformation and failure. Major topics: reinforced polymeric materials; strengthening mechanisms in crystalline materials; phase microstructure of materials and methods for their control; mechanisms and mechanics of viscoelasticity, creep and creep fracture; materials selection. Project laboratory provides opportunity for independent research into mechanical behavior of materials. Competency required in 2.31 and taken in term following.
L. Anand

2.34J The Mechanics of Fracture

(Same subject as 3.41J)
Prereq.: 2.31, 2.32
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 (New)

Prereq.: 2.30 or 2.31, 2.32
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 and energy for pure conservative and pure dissipative systems. Heat, temperature, first law of thermodynamics. Pure thermal systems. Equilibrium and reversibility. 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

2.451J 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, G. P. Beretta

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 structual 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.
G. P. Beretta, 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

Reviews analogies among heat, mass, and momentum transfer. Free and forced convection from theoretical and experimental viewpoint for laminar and turbulent flows in ducts and over flat plates and blunt bodies. Heat transfer coefficients at high velocities. Heat transfer-friction relationship in heat exchangers. Film and dropwise condensation. Boiling with forced and natural convection. Radiative heat transfer; heat transfer between surfaces, in absorbing media.
B. B. Mikić, M. A. El-Masri

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: finite difference 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.: 2.20 or 2.25 or 10.52; 2.51 or 2.55 or 10.50; or 22.312
G (2) **Next offered 1987-88**
3-0-9

See description under subject 22.36J.
W. M. Rohsenow, P. Griffith, N. E. Todreas

2.58J Radiative Transfer (A)

(Same subject as 10.74J)
Prereq.: 2.51 or 10.302
G (2) **Next offered 1987-88**
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 2.402, 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

Analytical approach to the engineering problems and performance analysis of internal combustion engines. Study of fluid flow, thermodynamics, combustion, friction, heat transfer and other factors affecting power, efficiency, and emissions. Design and operating characteristics of different types of engines: spark-ignition, stratified charge, diesel, and mixed cycle engines. Engine laboratory project. For graduate and selected undergraduate students.
J. B. Heywood

2.621 Gas Turbine Design (A) (New)

Prereq.: 2.20, 2.40 or 2.41J or 2.51
G (1) **Next offered l987-88**
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 exchanges, and combustion chambers. Operating characteristics of gas-turbine power plants in various applications. Alternate years.
D. G. Wilson

2.63 Energy Production from Renewable Resources (A)

Prereq.: 2.20, 2.51
G (2) **Next offered 1987-88**
3-0-9

Basic elements of energy production from wind, solar light, ocean waves, tides, geothermal gradients, and biomass. Significant physical properties of solar radiation, the atmosphere and the ocean which affect design and operation of energy-gathering machines and systems. System dynamics of production, storage, and demand. Elements of component design, including economic factors.
J. A. Fay

2.649 Low-Temperature Refrigeration (A)

Prereq.: 2.40
G (1)
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)
3-0-9

See description under subject 10.651J.
L. R. Glicksman, A. F. Sarofim

Experimental Engineering

2.671 Measurement and Instrumentation

Prereq.: 2.02
U (1, 2) LAB
2-3-4

Experimental techniques for observation and measurement of fundamental system variables such as: force, pressure, temperature, flow, and acceleration. Emphasizes electrical measurement, associated instrumentation, and understanding of statistical and dynamic implications. 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. 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 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 1987-88**
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. C. Unkel, J. C. Keck

Design

2.70 Introduction to Design

Prereq.: —
U (1)
2-3-4

Introduces design process in engineering, stressing creativity and visual thinking. Instruction is focused on design projects carried out by students working closely with section instructors. Lecture topics range from brainstorming to basic machine elements. Includes a design-and-build project. Designer's responsibility and professionalism are emphasized.
W. C. Flowers

2.701 Visual Communication in Design

Prereq.: —
U (1, 2)
2-2-2

Lectures and laboratory sessions on basics of drafting as used to delineate engineering design information and data. Introduces descriptive geometry, orthographic projection, sectional anauxiliary views, techniques of dimensioning and tolerancing, and computer-aided drafting. Use of drafting tools explained and practiced in addition to orthographic and pictorial sketching techniques.
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. Typically two or more individual design projects selected to employ a variety of machine elements, demanding integration into a functional and practical device. 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 or 2.31, 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) **Next offered 1987-88**
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) **Next offered 1987-88**
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 which 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

2.733J Engineering Design in Social Context

(Same subject as STS 430J)
Prereq.: —
U (2) HASS **Next offered 1987-88**
3-0-6

See description under subject STS 430J.
L. L. Bucciarelli

2.741 Fundamentals of Mining Technology (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
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 1987-88**
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, G. L. Brownell, A. C. Nelson, Staff

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 1987-88**
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 desiring 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, including 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 HST 570J)
Prereq.: Permission of Instructor
G (S)
6-6-6

See description under subject HST 570J.
D. Rowell, R. V. Kenyon, 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

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.
B. B. Mikić, 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 fretting and 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

2.820 Polymer Processing (A)

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.
G. Gutowski, D. 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 for Manufacturing Automation (A)

Prereq.: 2.14
G (2)
3-0-9

Provides background for applying computer-based control system techniques to batch manufacturing processes. Follows a brief review of classical control concepts and servosystems with an in-depth study of the modeling and control problems associated with several manufacturing processes. These include metal cutting, metal forming, and welding processes.
D. E. Hardt

2.835 Robot Design and Control (A) (Revised Content)

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) (New)

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. 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

2.86 Manufacturing Processes and Systems (Revised Content)

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.
M-K. Tse

2.900 Biomedical Materials

Prereq.: 2.901J or 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

Polymers and Fibers

2.901J Structure and Properties of Polymers

(Same subject as 3.061J)
Prereq.: 3.091 or 5.11, 3.00
U (2)
3-0-6

See description under subject 3.061J.
I. V. Yannas, D. R. Uhlmann

2.907 Science and Engineering of Biological Membranes and Structural Tissue (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Covers biophysical design and function of the cellular membrane and of skin considered as a membrane. First part: introduces basic molecular components of the cellular membrane, models of membrane structure and experimental models of membrane proteins. Second part: molecular biology of components of skin (collagen, elastin, mucopolysaccharides, protein polysaccharides), interaction of fibrous components with the protein polysaccharide matrix, physiological and pathological aspects of structural tissue, and an analysis of skin as an engineering composite material.
I. V. Yannas

2.921 Polymer Deformation and Fracture (A)

Prereq.: 2.30 or 2.31, 2.32
G (2)
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, 2.31, 2.32
G (2) **Next offered 1987-88**
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, 2.31, 2.32
G (2) **Not to be offered 1987-88**
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

Special Studies

2.941J Invention

(Same subject as 13.77J, 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.
D. G. Jansson, 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. G. Jansson

2.943 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2)
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.: Permission of Instructor
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.
D. G. Jansson, W. C. Flowers

2.951 Engineering Internship

Prereq.: —
U (1, 2, S)
0-6-0

2.952 Advanced Engineering Internship (A)

Prereq.: 2.951
G (1, 2, S)
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) period between terms. 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
D. G. Wilson

2.981J Project Proseminar in Technology and Policy I (A)

(Same subject as TPP 11J)
Prereq.: Permission of Instructor
G (1)
4-0-8

2.982J Project Proseminar in Technology and Policy II (A)

(Same subject as TPP 12J)
Prereq.: TPP 11J
G (2)
4-0-8

See description under subjects TPP 11J and TPP 12J.
T. B. Sheridan, J. T. Kildow, L. L. Bucciarelli

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)
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

3 Materials Science and Engineering

3.UR Undergraduate Research

Prereq.: —
U (1, 2, S)
Arr.

Extended participation in work of a research group; includes independent study of literature, direct involvement in group's research commensurate with student skills, project work under an individual faculty member. See UROP coordinator for registration procedures.
C. V. Thompson

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.
R. M. Rose

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.
R. E. Spjut

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. R. Sadoway

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.
S. M. Allen

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 their relation to processing and properties. Attention to glass formation, phase separation, viscous flow and relaxation, glass melting and forming. Consideration of applications such as: glass-ceramic materials, fast-ion conducting glasses, optical waveguides, amorphous semiconductors and thin glassy films, 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

3.061J Structure and Properties of Polymers

(Same subject as 2.901J)
Prereq.: 3.091 or 5.11, 3.00
U (2)
3-0-6

Structure and properties of bulk polymers. Design of engineering materials based on polymers. Molecular weight and configurations of macromolecules, rubber elasticity, deformation and fracture, electrical and optical properties, polymer-based composite materials. Relationship between processing and morphology. Amorphous and semicrystalline polymers treated.
D. R. Uhlmann, I. V. Yannas

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.
G. E. Wnek

3.064 Polymer Engineering

Prereq.: 3.11, 3.185
U (2)
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 Laboratory

Prereq.: 3.081, 3.11
U (2)
1-6-5

Synthesis of typical plastics. Methods of processing. Techniques of polymer characterization: IR, DSC, viscosity, density, dynamic mechanical analysis, light scattering, microscopy, photoelasticity. Also modulus, strength, impact, creep, time-temperature superposition, environmental stress cracking.
D. K. Roylance, G. E. Wnek

3.069 Ceramics Processing

Prereq.: 3.07, 3.185
U (2)
3-0-6

Principles for processing technical ceramics based on an understanding of and application of fundamental principles for reliable and reproducible manufacturing. Case studies: ferrite magnets, alumina chip carriers, oxide varistors, and heat engine components. Topics: powder formation and conditioning, powder packing, densification and microstructure development, melt and vapor processing. Description of industrial manufacturing processes and how these relate to the fundamental concepts.
H. K. Bowen

3.07 Introduction to Ceramics

Prereq.: 3.01 or 10.14, 3.13
U (1) SD
3-0-6

Characteristics of the crystal structures, including crystal defects, of oxide materials and local atomic arrangements in silicate glasses discussed with regard to relative stability of alternate possible arrangements and influence of structure on properties. Applies phase equilibria, interface properties, atomic mobility, and phase transformations to development of structure discussed together with relationship of structure to certain physical properties. Individual study of a particular ceramic, ceramic property, or ceramic process selected by the student required.
W. D. Kingery

3.070J Materials for Nuclear Applications

(Same subject as 22.070J)
Prereq.: 3.091 or 3.14 or 3.071J
U (2)
3-0-9

See description under subject 22.070J.
R. G. Ballinger

3.071J Physical Metallurgy Principles for Engineers

(Same subject as 22.071J)
Prereq.: 3.091
U (1)
3-0-9

See description under subject 22.071J.
A. Mortensen

3.074 Glass, Ceramic, and Metal Forming

Prereq.: 3.091
U (2)
1-4-1

Plastic shaping of clays, blowing of glass, casting and brazing of metals in the laboratory to provide direct hands-on experience with materials behavior and forming methods. The principles involved in shaping materials and their historical development are explained and discussed.
W. D. Kingery

3.075 Ceramics and Glass Laboratory

Prereq.: 3.081
U (1)
2-7-3

Laboratory investigates ceramic and glass processing by means of a series of laboratory experiments plus an extensive project. Laboratory experiments cover a range of powder and glass processing together with physical property measurements. Laboratory project is undertaken with faculty supervision. Limited enrollment. Permission of instructor required.
Y-M. Chiang

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, K. C. Russell

3.084 Electronic Materials Project Laboratory (Revised Unit)

Prereq.: 3.147J
U (1)
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 which include fabrication and characterization phases.
C. V. Thompson

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.
J. B. Vander Sande, A. F. Witt

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.
B. L. Averbach

3.095J Introduction to Mining and Mineral Technology

(Same subject as 1.384J, 12.043J)
Prereq.: —
U (1)
3-0-6

A basic introduction to mining and the minerals industry with emphasis on state-of-the-art technology. Includes mineral exploration, surface and underground mining, extractive metallurgy, health and safety, and environmental considerations. Integration of diverse subject matter stressed. Guest lectures by a variety of faculty members, classroom discussions based on assigned reading.
J. F. Elliott, R. G. Burns, H. H. Einstein, C. R. Peterson

3.10 Chemical Physics of Materials

Prereq.: 3.01 or 10.14, 3.13, 18.03
U (1) SD
4-0-8

Introduction to quantum physics of electronic structure and chemical bonding of atoms, molecules, and solids. Emphasis on those concepts which 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.
G. Kalonji

3.11 Mechanics of Materials

Prereq.: 8.01, 18.02
U (1) SD
4-0-8

Aspects of solid mechanics necessary for understanding the response of polymers, metals, and ceramics to applied loads; static equilibrium, states of stress and strain, material stress-strain-temperature relations, response to torsion and bending, stability. Subject includes an introduction to computational mechanics, including FORTRAN student projects.
D. K. Roylance

3.13 Structure of Solids

Prereq.: 8.02
U (2)
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.
B. J. Wuensch

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 history, microstructure, and properties of each alloy system illustrated by case studies. Fracture analysis of alloys widely used in engineering applications emphasized.
N. J. Grant, R. M. N. 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

3.146 Electronic Materials

Prereq.: 3.10
U (1)
3-0-6

Various aspects of semiconductors such as crystal growth, impurity segregation, crystal structure, and electronic properties relevant to device applications. Emphasizes relationships among structure, bonding, and properties in elemental and compound semiconductors.
H. L. Tuller

3.147J Microelectronics Processing Technology (Revised Content and Unit)

(Same subject as 6.701J, 10.611J)
Prereq.: 3.185
U (1, 2)
3-4-5

Introduces 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 interrelationships between material properties, device structure and electrical behavior of devices. Provides background for thesis work in electronic materials and 3.084.
D. A. Rudman, C. V. Thompson, D. J. Edell, R. T. Howe, H. H. Sawin, C. G. Sodini

3.15 Electrical, Optical, and Magnetic Materials and Devices

Prereq.: 3.10
U (2)
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

3.17 History and Anthropology of Materials Technology

Prereq.: —
U (1) **Not to be offered 1987-88**
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.
H. N. Lechtman

3.171 Ceramic Artifact Interpretation

Prereq.: —
U (2) **Next offered 1987-88**
1-3-5

Ceramic artifact examination and interpretation form the basis for failure analysis, product development, and many inferences in archaeology, art history, and the history of technology. In combination with laboratory investigations of actual artifact samples, seminar discussions focus on the nature of the induction process applied to artifact data. In particular, the use of statistical hypotheses and the nature of plausible reasoning examined as applied to materials technology. Limited enrollment. Permission of instructor required.
W. D. Kingery

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.: 2.31, 2.32 or 2.30 or 2.301
G (2) **Next offered 1987-88**
3-0-9

See description under subject 2.302J.
A. S. Argon

3.26J Micro Mechanisms of Fracture (A) (New)

(Same subject as 2.303J)
Prereq.: 2.31, 2.32 or 2.30 or 2.301
G (2) **Next offered 1987-88**
3-0-9

See description under subject 2.303J.
A. S. Argon

3.27 Diffraction and Structure (A)

Prereq.: 8.03, 18.03
G (2) **Not to be offered 1987-88**
4-0-8

X-ray and neutron production, absorption, and scattering. Overview of symmetry theory, point groups, and space groups. Interprets diffraction effects through the Ewald construction, reciprocal lattice, and Fourier transforms. Instrumentation and the interpretation of diffraction patterns produced by the Laue, Debye-Scherrer, Weissenberg, and precession techniques. Diffractometer geometries. Applies diffraction to determination of particle size, pole figures, texture, and crystal structure.
B. J. Wuensch

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, 3.12, 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 (1)
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)
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) (New)

Prereq.: —
G (1)
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

3.35 Solidification Processing (A)

Prereq.: 3.02
G (2)
2-0-4

Principles of control of structure, properties, and shape in processes involving liquid-solid and vapor-solid transformations. Heat flow, solute redistribution, nucleation, growth kinetics. Resultant structures and properties. Examples drawn from commercial processes, including metal casting, zone refining, electrodeposition, and crystal growth from the melt, vapor, and solution.
M. C. Flemings

3.36J Welding Engineering (A)

(Same subject as 13.17J)
Prereq.: 3.02 or 3.141
G (1)
3-0-6

See description under subject 13.17J.
K. Masubuchi

3.37 Welding and Joining Processes (A)

Prereq.: 3.185
G (2)
2-0-4

Discusses a wide variety of processes and materials from the viewpoint of their fundamental physical and chemical properties. Specific topics: cold welding, 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 or 3.141
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. M. N. Pelloux, R. G. Ballinger

3.40 Physical Metallurgy (A)

Prereq.: 3.02, 3.11
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.: 2.31, 2.32
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 (A)

Prereq.: 3.15 or 6.012, 6.301
G (2)
2-0-6

Properties and reactions of materials systems which are used in semiconductor device technology. A fundamental and practical approach to structure, imperfections, defect equilibrium, and processing developed. The source of the electrical, optical, and magnetic properties of both homogeneous and heterogeneous structures derived. A macro- and microscopic approach to the phenomena of reactivity, metastability, and diffusion included.
L. C. Kimerling

3.47 Electronic Materials Processing (A)

Prereq.: 3.20, 3.21, 3.15
G (2)
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

3.49 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. C. Gatos

3.50 Physical Chemistry of Metallurgical Processes (A)

Prereq.: 3.20
G (2)
3-0-6

Studies physiocochemical 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 1987-88**
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

3.53 Electrochemical Processing of Materials (A)

Prereq.: 3.185
G (1) **Next offered 1987-88**
3-0-6

Principles of electrochemistry: thermodynamics and kinetics of electrode processes, thermodynamic and transport properties of aqueous and non-aqueous 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) **Not to be offered 1987-88**
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

3.551J Gas-Solid Reactions (A)

(Same subject as 10.48J)
Prereq.: 3.55, 10.50
G (2) **Next offered 1987-88**
3-0-6

Gas-solid reactions, involving single particles; chemical kinetics, heat and mass transfer, pore diffusion, and structural changes. Reaction of porous and non-porous particles, reactions between solids, proceeding through gaseous intermediates. Reviews experimental techniques for study of gas-solid reactions, including physical characterization of solid specimens. Multi-particle systems, such as packed beds, fluidized beds, and rotary kilns. Gas-solid reactions of industrial importance.
J. Szekely

3.552 Mathematical and Physical Modeling of Materials Processing Operations (A)

Prereq.: 3.55
G (1) **Not to be offered 1987-88**
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)

Prereq.: 3.56
G (2) **Next offered 1987-88**
3-0-6

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.
R. de Neufville, J. P. Clark

3.561 Materials Systems Analysis (A)

Prereq.: 3.56
G (2) **Not to be offered 1987-88**
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 (1)
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.
D. G. Jansson

3.57 Particulate Technology (A)

Prereq.: 3.21
G (2) **Next offered 1987-88**
3-0-6

Methods of particle size analysis are presented in detail to set the stage for a discussion of the following ceramic and metallurgical processes in particulate technology: comminution classification, sedimentation, crystallization, agglomeration, and powdered metal generation. Analysis of these topics provides familiarity with population balance theory of particulate processes.
T. A. Ring

3.576J Law, Technology, and Public Policy

(Same subject as TPP 32J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject TPP 32J.
N. A. Ashford

3.577 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2)
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 materals 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

3.59 Research Proposals — Planning for Discovery (A)

Prereq.: —
G (2) **Next offered 1987-88**
2-0-4

Analyzes individual research proposals aimed at new discoveries in relationship to concepts such as market for discovery, importance of paradigms, importance of anomalies, influence of communities, distinction between discovery and proof of discovery, and nature of plausible reasoning. Requires preparation of research proposals and includes individual counseling and evaluation by a faculty member other than advisor or thesis supervisor. Limited enrollment. Permission of Instructor required.
W. D. Kingery

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 1987-88**
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 1987-88**
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

3.602 Mechanical Properties of Ceramics (A)

Prereq.: —
G (2) **Next offered 1987-88**
3-0-6

Discusses use of ceramics as structural materials including both fracture and deformation as related to engineering applications.
R. L. Coble

3.604 Problems in Nonstoichiometry (A)

Prereq.: 3.601
G (1) **Not to be offered 1987-88**
2-0-4

Derives thermodynamics of nonstoichiometric phases and analyzes inherent limitations of this approach. Extends theory to highly defective systems. Applies defect chemical analysis to binary and higher order systems. Analyzes cluster models and extended defects in highly nonstoichiometric systems. Examines implications of defect structure on structural, kinetic, electrical, and other properties of such materials.
H. L. Tuller

3.61 Glass Structure and Properties (A)

Prereq.: 3.06 or 3.07
G (1) **Not to be offered 1987-88**
3-0-6

Considers topics of interest in the science and technology of amorphous solids, including glass formation, crystallization of glass-forming liquids, flow and relaxation phenomena, structure of glasses, phase separation in glasses, mechanical, electrical, and thermal properties of glasses. Emphasizes information from recent publications. Alternate years.
D. R. Uhlmann

3.611 Polyphase Ceramics (A)

Prereq.: 3.06, 3.07
G (2) **Not to be offered 1987-88**
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.
W. D. Kingery, D. R. Uhlmann

3.63 Ceramic Processes (A)

Prereq.: 3.06 or 3.08, 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.
R. L. Coble

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.
W. D. Kingery

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. R. Sadoway

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.)
R. M. Latanision

3.71J Physical Metallurgy Principles for Engineers (A)

(Same subject as 22.71J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 22.71J.
A. Mortensen

3.711J Materials for Nuclear Applications (A)

(Same subject as 22.70J)
Prereq.: 3.14 or 3.71J
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.: 3.14 or 22.71J
G (1) **Not to be offered 1987-88**
3-0-9

See description under subject 22.72J.
R. G. Ballinger

3.73J Radiation Effects in Crystalline Solids (A)

(3.721J)
(Same subject as 22.73J)
Prereq.: 3.02 or 3.71J or 22.071J or 22.71J, 3.39J
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 1987-88**
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) **Not to be offered 1987-88**
3-0-6

See description under subject 3.17.
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.
M. S. Kazimi, O. Buyukozturk

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 and 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.
F. J. McGarry, K. Masubuchi

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.
F. J. McGarry

3.93 Materials Science of Polymers (A)

Prereq.: 3.061J, 10.691
G (1) **Next offered 1987-88**
3-0-9

Considers structure and properties of polymers from viewpoint of materials science. Specific attention to polymerization processes, melt and crystal structures, crystallization from the melt and dilute solutions, rheology and relaxation behavior, rubber elasticity, mechanical properties, and effects of orientation and fillers on various properties. Emphasizes student participation in class discussion.
D. R. Uhlmann

3.930 Industrial Practice (Revised Unit)

Prereq.: —
U (S)
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 (Revised Unit)

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

3.96 Spectroscopy and Electrical Properties of Polymers (A)

Prereq.: 3.062, or 10.641
G (2) **Not to be offered 1987-88**
3-0-9

The first two-thirds of subject focus on working knowledge of modern spectroscopic techniques (primarily UV-VIS, IR, and NMR) for determination of polymer composition, microstructure, and molecular dynamics. Selected instrumentation available for laboratory work. Also discusses topics of current interest concerning electrical properties including dielectric behavior and highly conductive polymers.
G. E. Wnek

3.961 Polymer Synthesis and Properties (A)

Prereq.: 10.691
G (1)
3-1-5

Fundamental chemistry of polymerization reactions. Reaction mechanisms and polymerization techniques. Emphasizes relationships among preparation, structure, and properties. Topics: coupling reactions, radical, ion, and coordination polymerization and chemical modification of polymers.
G. E. Wnek

3.97 Polymer Laboratory II (A) (New)

Prereq.: Permission of Instructor
G (2)
1-5-6

Techniques for characterizing morphology and physical properties of polymers; polymer rheology.
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.
D. R. Uhlmann

4 Architecture

4.UR Undergraduate Research in Architecture

Prereq.: —
U (1, 2)
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

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

4.125, 4.126 Architectural Design[1] (Revised Unit)

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] (Revised Unit)

Prereq.: 4.125, 4.126
U (1, 2)
0-12-9

4.143, 4.144 Architectural Design (A)[1] (Revised Unit)

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] (Revised Unit)

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 the evaluation of the staff independently of formal grades accumulated.

4.160 Urban Settlement Design in Developing Countries I (A) (Revised Unit)

Prereq.: Permission of Instructor
G (2)
0-12-9

4.161 Urban Settlement Design in Developing Countries II (A) (Revised Unit)

Prereq.: 4.160
G (1)
0-12-9

Advanced projects on urban settlement environments 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) (Revised Unit)

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 which 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)
(Revised Unit)

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

4.17, 4.171 Special Problems in Architectural Design

Prereq.: —
U (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

4.181-4.183 Architectural Design Workshops (A)
(New)

Prereq.: 4.131, 4.132 or 4.143, 4.144
G (1, 2)
Arr.

Form-making exercises which 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

4.19, 4.191 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

4.201J Structuring Computer Programs for Architecture and Planning
(New)

(Same subject as 11.015J)
Prereq.:—
U (1)
4-4-4

See description under subject 11.015J
A. Fleisher

4.203 Computers and Architecture I

(4.201)
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)
(New)

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 Design with Computers (A)
(Revised Content)

Prereq.: 4.143, 4.204
G (2)
4-0-8

Explores architectural design projects, both on the micro and macro level. A combination of microcomputer-aided design and pencil-based design methods facilitate the exploration of easy scale changes (zooming) and the insertion of building elements and components, from preliminary site diagramming to the specifics of construction details. 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 which 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

4.241 3-D Computer Graphics

Prereq.: —
U (1)
4-0-8

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

4.242 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

4.245 Computers and Graphics

Prereq.: Permission of Instructor
G (1)
4-2-6

A general introduction to computer graphics and its applications in design, architecture, and the graphic arts. Practical assignments provide experience in the use of 2-D and 3-D graphics in the extensive facilities of the Media Laboratory, including touch-sensitive screens, color raster displays, and computer-linked video systems. PL1 is the programming language most in use. Programming experience not mandatory. Open to undergraduates. Consult Department headquarters.

4.251 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

4.254J Mass Communications Technology and Policy (A)

(Same subject as 17.742J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 17.742J.
A. Lippman, W. R. Neuman

4.258, 4.259 Special Projects in Computer Graphics and Communications (A) (New)

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

4.26 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.
F. Domeyko-Perez

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.
J. R. Myer

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.
E. Robbins

4.276 Introduction to Building Economics

Prereq.: Permission of Instructor
G (2)
4-2-6

Introduces basic analytical concepts of micro and macroeconomics, with applications to building and the building industry. Prepares for microeconomic analysis of firms engaged in planning, real estate development, design, construction, and maintenance of buildings, as well as for macroeconomic analysis of the building industry in developed and developing countries. This subject satisfies the economics requirement for the S.M.Arch.S. program.
R. Bon

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.
L. J. Gibson

4.331 Synthesis of the Behavior of Structural Systems I

Prereq.: —
G (1)
4-0-4

4.332 Synthesis of the Behavior of Structural Systems II

Prereq.: 4.331
G (2)
4-0-4

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)
4-0-4

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

4.39 Special Problems in Structural Design (A)

Prereq.: 4.30 or 4.331
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

4.402J Building Construction I

(Same subject as 1.411J)
Prereq.: —
U (1)
4-0-8

Basic principles of materials and methods of construction as applied to common generic building types. Emphasizes integrated systems approach from preliminary design to on-site implementation.
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 (2)
2-4-3

Technical analysis and on-site case studies of selected building projects and/or their constituent sub-systems and elements. Investigates operational integration and technical implementation of materials and processes to realize explicitly stated design criteria by means of best current building practice. Develops construction documentation, details, and basic specifications within given limits of codes, regulations, and other legal restrictions.
E. Dluhosch

4.409 Special Problems in Building Technology (A)

Prereq.: 4.30, 4.402J, 4.43
G (2)
Arr.

Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff.
E. Dluhosch

4.43 Acoustics in Architecture and Planning

Prereq.: 4.402J
U (1)
4-0-4

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.
H. J. Bryan

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.
H. J. Bryan

4.468 Energy Conscious Design (A)

Prereq.: 4.071J, 4.131 or 4.143, 4.45, *4.46*
G (2)
4-4-12

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.
H. J. Bryan

4.48 Integration of Mechanical Systems (A) (New)

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.
H. J. Bryan

4.51 Building Systems I

Prereq.: Permission of Instructor
G (1)
3-0-6

Technological innovation in building construction, including mechanization, prefabrication, industrialization. Analyzes processes for building system production and delivery on and off site. Applies appropriate building systems in both industrialized and developing countries. Lectures, case studies, and field trips.
E. Dluhosch

4.52 Building Systems II - Workshop (A) (Revised Content and Unit)

Prereq.: 4.51
G (2)
0-12-9

Development of a coordinated building system for a selected generic building type. Application of performance concept to the selection, procurement, and deployment of materials, elements, components, and/or sub-systems to be assembled on or off-site, based on explicit rules of dimensional and positional coordination. Testing of design solution against alternative technological implementation process. Emphasis on resolving a given basic design concept in terms of a fully developed technical solution.
E. Dluhosch

4.55 Building Economics: Project Life Cycle Analysis (A)

Prereq.: 4.276
G (1)
3-0-6

Examines microeconomic aspects of building and building technology in framework of project life cycle analysis. Analyzes economic role of design professionals in network of key actors participating in project life cycle: planning, real estate development, design, construction, maintenance, reconstruction. Requires empirical research projects into life cycle phases and/or facets in a unified case study format.
R. Bon

4.56 Building Economics: Inter-Industry Analysis (A)

Prereq.: 4.276
G (2)
3-0-6

Studies macroeconomic aspects of building and building technology in framework of inter-industry analysis. Emphasizes input-output analysis and extensions: social accounting matrices, multiregional input-output analysis, development network analysis. Requires empirical research projects into industrial and regional interdependencies of building industry in developed and developing countries.
R. Bon

4.59 Special Topics in Systems Building (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.
E. Dluhosch

4.601 Topical Studies in the History and Theory of Art

Prereq.: —
U (1) 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) 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.
D. H. Friedman

4.615 Selected Topics in Architecture of the Ancient World

Prereq.: 4.605
G (1)
3-0-6

Analysis of role of mass, space, structure, light, surface, and related social, political, and economic factors in architecture and urban design from prehistory through Roman times. Open to qualified undergraduates. Permission of instructor required.
D. H. Friedman

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

4.635 Renaissance Architecture

Prereq.: 4.605
U (1) HUM-D
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

4.638 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 Baroque Architecture (A)

Prereq.: Permission of Instructor
G (2)
Arr.

Seminar on a selected topic from Baroque architecture. Requires original research and presentation of oral and written reports.
H. A. Millon

4.642 Modern Art from Impressionism to Cubism

Prereq.: —
U (2) HUM-D
4-0-5

Presents Cezanne, Gauguin, Van Gogh, and Seurat against a background of Impressionism and other 19th-century styles and their relationship to the Synthetist, Nabis, and Symbolist groups. Required readings from letters and other writings by the artists, their artist and writer friends, and their critics.
A. Wagner

4.644J Virgin, Harlot, Hysteria: Visual Imagery of Women in 19th-Century Culture (New)

(Same subject as SP 474J)
Prereq.:—
U (2) HASS
3-0-6

Examination of the representation of women in 19th-century European and American visual arts and literature: the forms it took, the beliefs it tapped, the myths it offered and sustained. A range of problems and themes common to the arts of the period — from female sexuality to feminism — viewed both in terms of specifically artistic procedures, and in relation to social reality and consciousness.
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

4.651 Modern Art from Cubism to the Present

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

4.654 Advanced Studies in Iconography and Symbolism (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Selected topics and guided research in iconography and symbolism in 19th- and 20th-century art. Registration subject to prior arrangement for subject matter and supervision by instructor.
W. V. Andersen

4.656 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

4.658 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 presupposition and methods. Open only to Ph.D. candidates and other advanced students.
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

4.671 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. The seminar to produce theoretical or critical essays, graphic analyses, formalizations or designs. Limited enrollment.
S. Anderson

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

4.681 Introduction to Building in East Asia

Prereq.: —
U (2) HASS
3-0-6

Promotes understanding of society in East Asia through the study of conscious and unconscious making, perception, and representation of the built environment as well as attitudes toward and behavior within it, both historically and at present. Historical and anthropological approach. Emphasizes India, China, and/or Japan.
G. Nitschke

4.682 Selected Topics in the Study of East Asian Architecture (A)

Prereq.: Permission of Instructor
G (2)
2-0-7

Research seminar on the development, structure, and module of the traditional Japanese house and garden and their relation to folk and religious architecture as well as to their urban contexts or their setting in nature. Historic and structural approach based on measured drawings and translations of early texts on the subject written by craftsmen, priests, and literati.
G. Nitschke

4.683J The "Islamic City": History, Culture, and Form

(Same subject as 21.482J)
Prereq.: Permission of Instructor
G (1)
3-0-6

Introduces Islamic civilization, past and present, through a study of the city in the Muslim world. Illustrates how the lenses of social and architectural history, anthropology, and planning reveal different phenomena in the city and different aspects of urban culture and form. Examines the extent to which the socioeconomic, political, architectural, and spatial features of such cities as Fez, Cairo, and Lahore can be explained in terms of Islam.
P. S. Khoury, Y. Tabbaa

4.684 Islamic Architecture

Prereq.: —
U (1) HASS
3-0-6

Survey of Islamic architecture from its origins in the late antique world to the pre-modern world. Examines the formation of early Islamic architecture and a "classical" style; the development of regional schools from Spain to India; and the eventual synthesis of these traditions within the architectural styles of the Ottomans of Turkey, the Safavids of Iran, and the Mughals of India.
Y. Tabbaa

4.685 Islamic Architecture from the Ottoman Empire to the Present (A)

Prereq.: —
G (2)
3-0-6

Islamic Architecture in Turkey and the Arab Middle East from the Ottoman Empire to the modern period. Examines the structural, formal, and symbolic elements of Ottoman architecture in the capital and the provinces, the penetration of European architectural styles in the 18th and 19th centuries, and the search for an "appropriate" style throughout the present century.
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

4.694 Advanced Study in East Asian Architecture

Prereq.: Permission of Instructor
G (2)
Arr.

Seminar on a selected topic from East Asian architecture. Requires original research and presentation of oral and written reports.
G. Nitschke

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 the 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, concludes by examining consequences for the design of built form.
R. Lewcock

4.721J Introduction to the Development Industry (New)

(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

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ion and Dye Lasers, CW and Pulsed CO_2 Lasers, Raman Spectrometer, microcomputers, and several auxiliary signal processing equipments.

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 offers interdepartmental master's and doctoral degree programs in statistics and helps to coordinate research, teaching, and consulting activities in statistics at MIT. 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. (**Undergraduates** can focus on statistics in a number of departments, particularly Mathematics, Economics, and the Sloan School of Management.)

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 pattern recognition and cluster analysis, robust regression, categorical data analysis, statistical computing and graphics, detection of influential data, time series analysis, stochastic control, sequential analysis, Bayesian statistics, risk assessment, and probability theory.

Fields of application have ranged from microbiology and astrophysics to political science, and from the health sciences to the Massachusetts lottery. Departments in which Center members are involved include Mathematics; Electrical Engineering and Computer Science; Earth, Atmospheric, and Planetary Sciences; Economics; Applied Biological Sciences; Civil Engineering; 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, 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 60 statistics subjects offered at MIT, may be obtained by contacting the Office of the Director, Professor Roy E. Welsch, Room E40-129, MIT, Cambridge, Massachusetts 02139, (617) 253-8411.

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 relationship between 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 1-171, MIT, Cambridge, MA 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 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 complete 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 15.012 Applied Macro and International Economics; 3) the legal and political context of policy development, and specifically 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 a minimum core of two subjects, 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 Engineering Policy Thesis 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 20 students each year. We limit the class 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 Chairman, Professor Richard de Neufville, Room 1-138, MIT, Cambridge, Massachusetts 02139, (617) 253-7693, the Associate Chairman, Professor Joel Clark, Room 8-413, 253-6885, or the Director of the Center for Technology, Policy, and Industrial Development, Professor Daniel Roos, Room E40-202, 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. 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 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) 253-5049.

Students interested in research also may contact various laboratories and centers directly. For information about the opportunities for interdisciplinary research, see the descriptions 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. Therefore, it is helpful to look through all of the offerings for topics that may be of interest.

For more details about the program, including titles and descriptions of seminars, see the *Undergraduate Seminar Booklet* issued twice yearly. This publication is available from the Undergraduate Seminar Office, Ms. Peggy Richardson, Room 7-143, 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

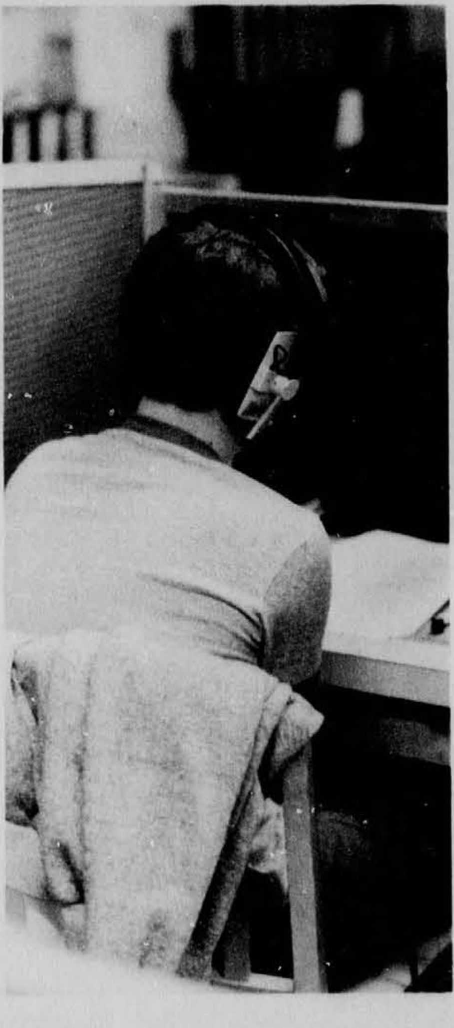
The George R. Wallace, Jr., Geophysical Observatory is a unique research facility designed to monitor ground motions and to aid in the development and testing of new seismic and other geophysical instrumentation. It is the center of activity for MIT's nine-station network in New England.

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 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. 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 Toksöz, Room E34-440, MIT, Cambridge, Massachusetts 02139, (617) 253-7852.

Women's Studies Program

The Women's Studies Program offers unique opportunities for interdisciplinary study and research for both **undergraduate** and **graduate students.** The Program's courses focus on the social, historical, and cultural contributions and perceptions of women, and can provide a Humanities concentration for undergraduates. 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 URCP projects can be arranged. 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 biology, psychology, engineering, and literature. 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.



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 consists of the Department of Architecture and the Department of Urban Studies and Planning. The departments offer undergraduate, graduate-professional, and doctoral programs in architecture, planning, and media arts and sciences, which prepare students for practice, research, and further study. Students have had a wide variety of field experience in private and public sector programs.

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.

The School's academic programs are shaped by the search for new knowledge, including independent scholarly research, with its written products, and the consulting work that individuals carry out, often as members of architecture and planning firms.

As part of a great research institution, the School provides a base for research in two laboratories — the Laboratory of 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, and, beyond the Institute, through the MIT-Harvard Joint Center for Housing Studies. 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 Laboratory projects have represented the areas of energy conservation and appropriate technology, 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.

Media Laboratory

In the late 1940s, MIT pioneered in relating experiments in science and engineering to the arts, which suggested an alliance through visual education of scientists and through the opportunity for artists to be stimulated by the tools and constructs of science and technology. In 1963, innovations in computer systems manipulating 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 arts and media technology facility, which 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. Some current Media Laboratory projects cover computer graphics, home computing, speech recognition, and studies of the school of the future.

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 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

Barbara Lister-James
Assistant Dean for Administration

Cynthia Ware, B.A.
Communications Coordinator

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

Department of Architecture

John Randolph Myer, B.Arch.
Professor of Architecture
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
(On leave, spring)

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

N. John Habraken, B.I.
Professor of Architecture

Imre Halasz, Dipl. Arch.
Professor of Architecture

Richard Leacock, D.F.A.
Professor of Cinema

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

Henry A. Millon, B.Arch., M.Arch., Ph.D.
Professor of History and Architecture
(Visiting)

Nicholas Peter Negroponte, M.Arch.
Jerome B. Wiesner Professor of Media Technology
Director, Media Laboratory

Seymour Aubrey Papert, Ph.D.
Professor of Media Technology

Otto Piene, M.A.
Professor of Visual Design
Director, Center for Advanced Visual Studies

William Lyman Porter, M.Arch., Ph.D.
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Maurice Keith Smith, B.Arch.
Professor of Architecture

Jerome Bert Wiesner, Ph.D.
Institute Professor, Emeritus
President, Emeritus

Waclaw Piotr Zalewski, D. Tech. Sci.
Professor of Structures

Associate Professors

Stephen Benton, Ph.D.
Associate Professor of Media Technology

Muriel Cooper, B.F.A.
Associate Professor of Visual Studies

Eric Dluhosch, M.Arch., Ph.D.
Associate Professor of Building Technology

Fernando Domeyko-Perez, Dipl. Arch.
Associate Professor of Architecture

Richard Filipowski, B.A.
Associate Professor of Visual Design

David Hodes Friedman, Ph.D.
Associate Professor of the History of Architecture

Nabeel Hamdi, Dipl. Arch.
Associate Professor of Housing Design

Sandra C. Howell, Ph.D.
Associate Professor of Behavioral Science in Architecture

Jeffrey H. Kulik, Ph.D.
Associate Professor of Media Technology
(Visiting)

Andrew Lippman, M.S.
Associate Professor of Media Technology

Robert J. Slattery, M.Arch.
Associate Professor of Architecture

Chester Lee Sprague, M.Arch.
Associate Professor of Architecture

Jan Wampler, M.Arch.
Associate Professor of Architecture

Assistant Professors

Ranko Bon, Ph.D.
Assistant Professor of Economics in Architecture
George Macomber Career Development Assistant Professor in Construction Management

Rosemary Grimshaw, M.Arch.
Assistant Professor of Architecture

Tod Machover, M.M.
Assistant Professor of Media Technology

Edward Robbins, Ph.D.
Assistant Professor of Anthropology in Architecture

Yasser Tabbaa, Ph.D.
Assistant Professor of the History of Architecture
Aga Khan Development Professor in the History of Islamic Architecture

Anne Wagner, Ph.D.
Assistant Professor of the History of Art

David Zeltzer, M.S.
Assistant Professor of Media Technology
NEC Career Development Professor of Computer and Communications

Adjunct Professors

Wayne V. Andersen, Ph.D.
Adjunct Professor of the History of Art

Giancarlo De Carlo, L.A.
Adjunct Professor of Architecture

Arun N. Netravali, B.Tch., M.S., Ph.D.
Adjunct Professor of Media Technology

Richard Chester Tremaglio, M.Arch.
Adjunct Professor of Architecture

Principal Research Associates

Reinhard Goethert, M.Arch., Ph.D.
Timothy E. Johnson, S.M.

Lecturers

Benjamin Bergery, B.A.
Nishan Bichajian
Michael Buckley, M.A.A.S.
Glorianna Davenport, M.A.
John Furlong, M.L.A.
Dennis Frenchman, M.Arch., M.C.P.
John Gianvito, S.M.Vis.S.
Bryan Harvey, Ph.D.
Shun Kanda, M.Arch.
Alan Kay, Ph.D.
Gunter Nitschke, Dipl. Arch.
Carl Rosenberg, M.Arch.
William Wright, B.S.E.E.

Instructors

David Levitt, Ph.D.
Frank Miller, M.Arch.

Technical Instructors

Vanessa Boris, M.A.
William F. Kelley, B.B.A.
Jason Kinchen, B.A.
Steven Kuettel, B.A.
Peter Randlette, B.A.

Administrative Officer

Anne Shepley, B.A.

Assistant to the Head of the Department

Nancy Jones, B.A.

Assistant Director for Administration and Finance, Media Laboratory

Robert P. Greene, B.S.

Administrative Assistants

Ellen Liao
Linda Okun, M.A.

Department of Architecture

(Course 4)

Professors Emeriti

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

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

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 stress in **Architecture studies** is on combining the study and practice of shaping the built environment with research on the built environment, on the forces which 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 research and teaching in building structures, construction processes, industrialized building systems, acoustics, energy in buildings, solar architecture, and daylighting. Faculty in the group offer subjects and design studio experiences examining the technical and/or contextual aspects of their fields. Students may then, for example, have the opportunity both to study problems of energy resources and technologies, and to use what they have learned in designing physical environments. Research facilities include the Program for Energy Efficient Buildings and Systems and the MIT Solar Building No. 5.

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 non-action. They study the development of and changes in significant attitudes about architectural works.

Undergraduate Study

The Arts and Media Technology facility was completed last academic year, during which time ten previously separate groups from three Schools moved together to create a new interdisciplinary laboratory called the Media Lab, and to begin an academic initiative called **Media Arts and Sciences.** The academic program includes an experimental Ph.D. in Media Technology, with concentrations in epistemology and learning, electronic media, and computer music. An established Master of Science runs concurrently, including a concentration in visual studies. The goal of both the research and academic programs is to bring together the invention and creative use of modern media in general and electronic means, with specific application to education, medicine, and the arts.

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 film making); 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.

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 a list of subjects which gives the 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][1]	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

4.070	Words, Images, Graphics, Tools, and Ideas, 12
4.26	Observing Form in Context, 12; 4.01

Group 3 Environmental Technology

4.241	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	Modern Art from Impressionism to Cubism, 9
4.645	Selected Topics in Architecture — 1750 to the Present, 9; 4.605
4.651	Modern Art from Cubism to the Present, 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
4.921	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**

1
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.

*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.

Graduate Study

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.

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: **at least 63**

One subject from each of the following six groups:

Group 1 Introductory Subject
4.01 Issues in Architecture, 12

Group 2 Design Information
4.241 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 Modern Art from Impressionism to Cubism, 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 Modern Art from Cubism to the Present, 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
4.921 Creative Photography I, 12
4.971 Introduction to Moviemaking, 12

Planned Electives: **75**

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 Visual Studies, the Master of Science in Architecture 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 Arts and Sciences.

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.

Eleven previously separate or new groups have been assembled from different Schools and departments at MIT to form a new and unique interdisciplinary laboratory in the Media Laboratory. These groups are: Electronic Publishing, Learning Research, Advanced Television, Computer Music, Spatial Imaging, Graphics, Human-Machine Interface, Telecommunications, Film and Video, Computer Graphics and Animation, and Computers and Entertainment.

As part of the curriculum, each student will negotiate with his or her advisor an exceptional distribution of introductory subjects to cover those areas in which the student has no previous proficiency or experience. Students in the degree program are required to complete their studies in a common culture which includes advanced placement or an MIT experience with computer programming, video technology, holography, and studies of epistomology. 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 which 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. Sub-areas of research and teaching are methods, behavior studies, technology and settlement design. 3) Building Systems Design — concentrating on the architectural applications of various aspects of the technology of building and their related systems. Emphasis is on energy systems, industrialized building systems, structural systems, and environmental control in building.
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. Sub-areas 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.

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.

A new experimental program under the Media Arts and Sciences Program has been announced, which leads to a Ph.D. in Media Technology. Initially there are three areas of concentration: electronic and communications media, epistomology and learning, and music and music cognition. The thrust of this new program is modern information technology serving as a vehicle for human expression, either artistic or intellectual.

Inquiries

Further information concerning undergraduate and graduate academic programs in the Department, admissions, financial aid, and assistantships may be obtained from: 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

Aaron Fleisher, Sc.D.
Professor of Urban and Regional Studies
(On leave, spring)

Robert M. Fogelson, Ph.D.
Professor of History and Urban Studies

Bernard Joel Frieden, M.C.P., Ph.D.
Professor of City Planning

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

Frank Sidney Jones, M.B.A.
Ford Professor of Urban Affairs

Langley Carleton Keyes, Ph.D.
Professor of City and Regional Planning

Richard Charles Larson, Ph.D.
Professor of Urban Studies and Electrical Engineering
Codirector, Operations Research Center

Gary T. Marx, Ph.D.
Professor of Sociology

James McKellar, M.Arch., M.C.P.
Professor of Architecture and Planning
Director, Center for Real Estate Development
(Visiting)

Karen R. Polenske, Ph.D.
Professor of Regional Political Economy and Planning
(On leave, spring)

William Lyman Porter, M.Arch., Ph.D.
Professor of Architecture and Planning

Martin Rein, M.S.W., Ph.D.
Professor of Sociology
(On leave)

Lloyd Rodwin, M.P.A., Ph.D.
Ford International Professor
Director, Special Program for Urban and Regional Studies (SPURS)

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
(On leave, spring)

Lance Taylor, Ph.D.
Professor of Nutritional Economics

Judith Tendler, Ph.D.
Professor of Political Economy
(On leave, fall)

Michael Wheeler, J.D., LL.M.
Professor of Law
(Visiting)

Associate Professors

Lawrence Bacow, J.D., Ph.D.
Associate Professor of Law and Environmental Policy
(On leave)

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

Marc Andres Louargand, Ph.D.
Associate Professor of Real Estate Finance
(Visiting, fall)

William Wheaton, Ph.D.
Associate Professor of Economics and Urban Studies

Assistant Professors

Denise DiPasquale, Ph.D.
Assistant Professor of Urban Studies and Regional Planning
(Visiting)

Merrie G. Klapp, Ph.D.
Assistant Professor of Environmental Studies and Planning
(On leave, fall)

Edwin Melendez, Ph.D.
Assistant Professor of Urban Studies and Planning

Lynne Beyer Sagalyn, M.C.P., Ph.D.
Assistant Professor of Planning and Real Estate Development
(On leave, fall)

Bishwapriya Sanyal, M.C.P., Ph.D.
Assistant Professor of Urban and Regional Planning

J. Mark Davidson Schuster, Ph.D.
Assistant Professor of Urban Studies and Planning
Assistant Department Head

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.

Lecturers

David L. Birch, D.B.A., Ph.D.
Senior Research Scientist, Laboratory of Architecture and Planning

Louise Dunlap, Ph.D.

Dennis Frenchman, M.C.P., M.Arch.
Director of Environmental Design

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

John Tasker Howard, M.C.P.
Professor of City Planning, Emeritus

Lisa Redfield Peattie, Ph.D.
Professor of Urban Anthropology, Emeritus

Department of Urban Studies and Planning

(Course 11)

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 which 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 which subsequently have been incorporated into the academic program.

Undergraduate Study

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 through a fieldwork assignment or 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 which helps develop skills in analysis and management. This specialization prepares students for subsequent work in government, public administration and management, and law.

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 IX — 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: 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	Economic Principles I, 9

Group III: Planning and Applied Social Research

11.003	Planning and Applied Social Research 1, 12; 11.007J, 14.01
17.203	Evaluation Research Laboratory, 12
11.188	Social Research Methods, 12
18.057	Computer Data Analysis Laboratory, 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 Urban Economics 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).

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.

Bachelor of Science in Planning
Course IX—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	Optimization Theory on Engineering Application, 12	
1.03	Introduction to Probability and Statistics for Engineers, 12; 1.02, 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.

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	Economic Principles I, 9	
Group III: Planning and Applied Social Research		
11.003	Planning and Applied Social Research I, 12; 11.007J, 14.01	
17.203	Evaluation Research Laboratory, 12	
11.188	Social Research Methods, 12	
18.057	Computer Data Analysis Laboratory, 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 Urban Economics 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		92-78
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	Optimization Theory on Engineering Application, 12
1.03	Introduction to Probability and Statistics for Engineers, 12; 1.02, 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 60**
Total Units Required for the S.B. Degree	**360**

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 Secretary, 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 which 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" which 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, 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:

Environmental Design involves conceptualizing and guiding changes in the spatial environment. Work in this area at MIT involves acquiring knowledge about the interactions between peoplo 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.

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.

Community Development integrates economic, social, and political theories of development with planning methods. Emphasis is on community planning, including the location and organization of community services and facilities; 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.

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 domestic, foreign, and international regional economic policies. Currently, special attention is paid to domestic issues and the application of regional input-output techniques.

Housing and Real Estate Development focuses on the planning and management of urban development, and especially on the design, location, and financing of housing. Emphasis is on analysis of the financial dimensions of real estate, public policies that affect housing conditions and 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.

Teaching and research in **Transportation Planning** take place in several departments at MIT. 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.

The HUD Intern Program, a special Federally funded program for minority M.C.P. students, provides tuition and fieldwork placements in public and nonprofit agencies.

Master of City Planning/Developing Areas Option

The requirements for this professional degree program 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. 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 Sub-National 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 which bridge the two fields or the definition of new roles which 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.

Simultaneous Master's Degrees in City Planning and Real Estate Development

Students who have been admitted to the Master of City Planning Program may propose programs which include as well all of the required subjects for the Master of Science in Real Estate Development. Information on this program is given under the School of Architecture and Planning at the beginning of this chapter. Students may submit a joint thesis and count some subjects completed for one degree toward the other, thereby decreasing the overall time required for the two degrees.

Doctor of Philosophy

Students seeking research or teaching careers in planning or urban studies may apply for admission to the doctoral program. Admission requirements are substantially the same as for the Master's degree; however, more emphasis is placed on academic preparation in the student's proposed area of specialization. We do not require a M.C.P. or equivalent for admission for Ph.D. studies.

The doctoral program emphasizes the development of fundamental research competence, and flexibility in the exploration of questions which no single discipline can address. Students work under the mentorship of a faculty advisor. They may center their work on any subfield in which the Department of Urban Studies and Planning has faculty expertise.

Recent establishment of the Center for Real Estate Development at MIT opens new opportunities for doctoral students to take advanced work in real estate and participate in the research program of the Center, which brings together faculty and students with active professionals in real estate development companies. Specialized work is available in such fields as real estate finance, development policies, and relationships between the public and private sectors in city development.

After successful completion of a required first-year doctoral paper and general examinations, each Ph.D. candidate must prepare a written doctoral dissertation evidencing the capacity to do independent research. To be eligible for financial aid, students in the Ph.D. program must be registered for at least 30 credit units each term.

Students must take oral and written general examinations in two fields: a broad intellectual discipline (design, economics, management science/operations research, organizational sociology, planning, public policy and politics) and an area to which this is applied (environmental and natural resource policy, environmental design/built environment, health policy, housing and real estate development, labor and employment policy, neighborhood community development and negotiation and dispute resolution). Students must also make an oral presentation of their dissertation proposal to department faculty.

Doctoral candidates require two to four terms of study in residence before taking their examinations and beginning their dissertations, although the process may require up to six terms, depending on prior preparation. The Ph.D. requires completion of at least 180 credit units. Previous work at MIT or elsewhere may count toward the degree. The general requirements for the Ph.D. are specified in Chapter IV.

Interested and qualified students can undertake joint doctoral programs with the Department of Political Science or the Department of Economics.

Master of Science in Urban Studies and Planning

The majority of graduate students in the Department are either Master of City Planning students or doctoral candidates. Under special circumstances, however, admission may be granted to candidates seeking the Master of Science degree. The general requirements for the S.M. are given in Chapter IV. For further information concerning the S.M. option, contact the Department Head, Room 7-344.

Non-degree Programs

A limited number of non-degree students are admitted to the Department each term. This **special student status** is especially designed for mid-career professionals interested in developing specialized skills, but it also is available to others.

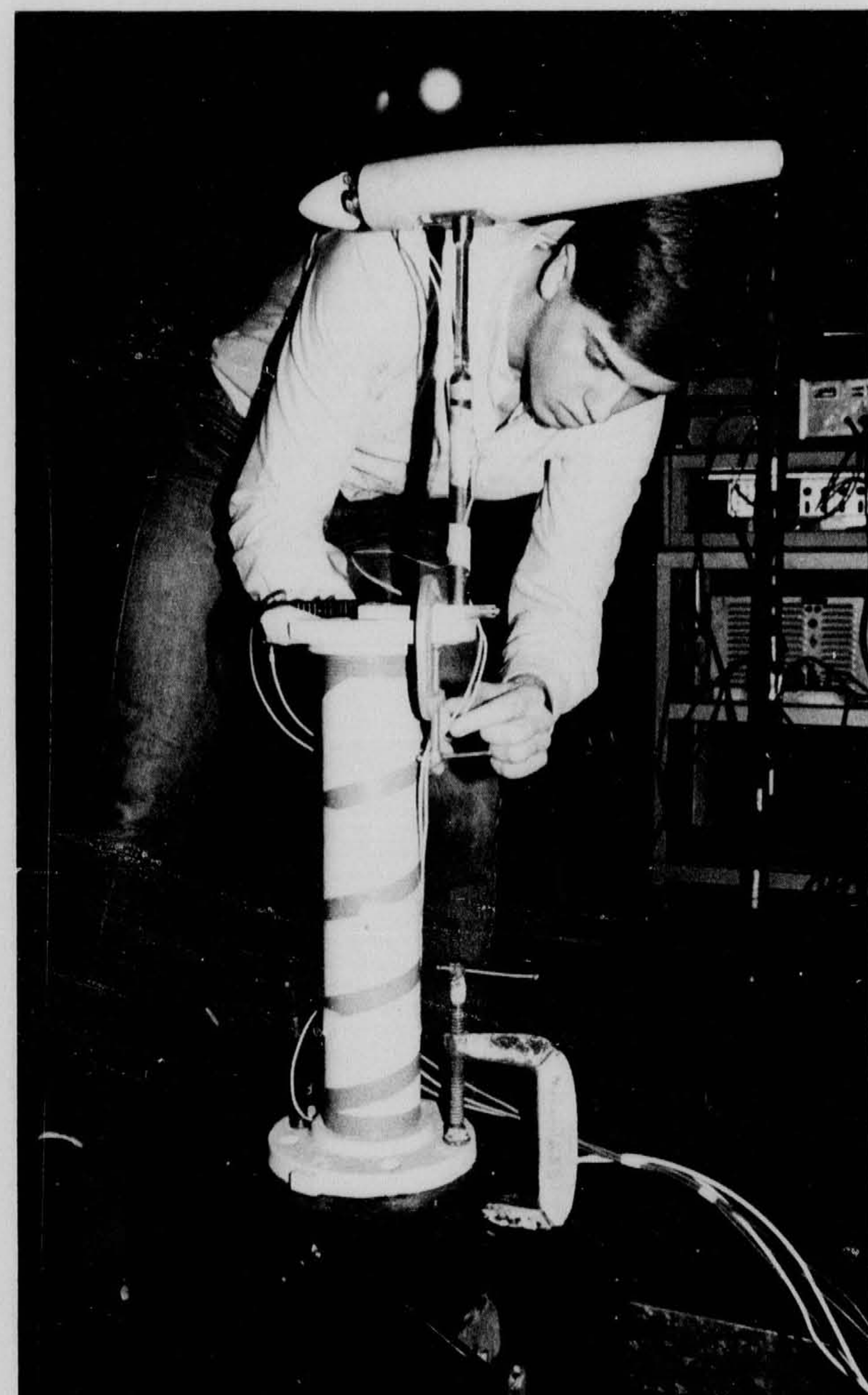
Every year 10 to 12 women and men from various parts of the United States are selected to participate in the **Community Fellows Program,** a 10-month non-degree program which seeks to expose the Fellows to a range of political and ideological positions bearing on the existence of people of color in America and the development of their communities. The Program promotes the belief that people of color in America cannot achieve maximal economic and political development without the sharing and/or pooling of their talents, skills, and resources.

The Special Program for Urban and Regional Studies of Developing Areas (SPURS) provides an opportunity for a small number of mid-career professionals to spend a year at MIT studying the problems of urban and regional change within a broad context of national development. The majority of students are from developing countries, and SPURS offers participants the opportunity to work with people interested in similar problems.

Further information on these non-degree programs is available from the Department.

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 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 which 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 advisor 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 degree 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. 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

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 558

Nuclear Weapons and Arms Control: Technology and Policy Issues G(1)
6.932, 13.93, 16.995, 17.486, 22.841

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

John Ronald Martuccelli, S.M.
Director, Engineering Internship Program

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

Edward Marc Greitzer, Ph.D.
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

Jean François Louis, Ph.D.
Professor of Aeronautics and Astronautics

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

Amedeo Rodolfo Odoni, Ph.D.
Professor of Aeronautics and Astronautics and Civil Engineering

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
(On leave)

Emmett Atlee Witmer, Sc.D.
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

Joseph Haralambos Haritonidis, 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

Bruce Keppen Walker, Sc.D.
Associate Professor of Aeronautics and Astronautics

Assistant Professors

David Lee Akin, Sc.D.
Assistant Professor of Aeronautics

Steven Robert Bussolari, Ph.D.
Charles Stark Draper Assistant Professor of Aeronautics and Astronautics

Mark Drela, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Antonio Luis Elias, Ph.D.
Boeing Assistant Professor of Aeronautics and Astronautics

Michael Bryce Giles, Ph.D.
Charles Stark Draper Assistant Professor of Aeronautics and Astronautics

Steven Ray Hall, Ph.D.
Boeing Assistant Professor of Aeronautics and Astronautics

Robert John Hansman, Jr., Ph.D.
Esther and Harold E. Edgerton Assistant Professor of Aeronautics and Astronautics

Daniel E. Hastings, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Lena Valavani, Ph.D.
Assistant Professor of Aeronautics and Astronautics

Andreas Hubertus von Flotow, Ph.D.
Assistant 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.
Robert Channing Seamans, Jr., Sc.D.
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.
John Hovorka, Sc.D.
Henry Herbert Kolm, Ph.D.
Stephen James Madden, Jr., Ph.D.
David Redding, Ph.D.
John Stanley Sinkiewicz, B.S.
Nawal Koshore Taneja, Ph.D.
John Pascal Vinti, Sc.D.
Leonard Stephen Wilk, M.S.
Joseph Yamron, S.B.

Technical Instructors

Allan Ralph Shaw
Edward Donald Weiner, A.S.E.E.

Administrative Officer

Helen Robbins Raine

Administrative Staff

Phyllis A. Collymore, A.A.
Anne M. Maynard
Elizabeth Zotos, B.A.

Senior Research Engineer

Charles McMaster Oman, Ph.D.

Research Associates

Robert David Bruen, M.S.
Robert Haimes, M.S.
James Francis Nash
Albert Thomas Supple, Jr., A.E.E.
Choon Sooi Tan, Ph.D.

Research Engineers

Raymond Anthony Ausrotas, M.S.
Frank Herman Durgin, E.A.A.
Dennis Francis Xavier Mathaisel, Ph.D.
John Demetrios Pararas, Ph.D.

Research Specialists

Paul H. Bauer, B.S.
Anne LaVin, B.S.
Robert Lee Renshaw, B.S.E.E.
Anthony John Scaltreto
Carl Francis Varnerin, B.S.

Research Staff, Administrative

Ping Mai Lee
Holly Esther Rathbun, A.S.

Department of Aeronautics and Astronautics

(Course 16)

Postdoctoral Associates

Belgacem Jery, Ph.D.
Xiaoliu Liu, Ph.D.

Visiting Scientists

Bertrand Kleinmann, Ph.D.
Alfred David Weiss, M.D.

Research Affiliates

James Draper, Ph.D.
Howard Theodore Hermann, M.D.
Byron Kurt Lichtenberg, Sc.D.
Alan Natapoff, Ph.D.
Nancy Lelewer Sonnabend, B.A.
Gregory Zacharias, Ph.D.

Visiting Engineer

Tamar Chuchem, S.M.

Visiting Scholars

Xing-Ren Wang, S.M.
Jin Zhang, B.S.

Professors Emeriti

Joseph Bicknell, S.M.
Professor of Aeronautics and Astronautics, Emeritus

Charles Stark Draper, Sc.D.
Institute Professor, Emeritus
Professor of Aeronautics and Astronautics, Emeritus
Senior Lecturer

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

Walter Wrigley, Sc.D.
Professor of Instrumentation and Astronautics, Emeritus

The objectives of the Department of Aeronautics and Astronautics are to provide a broad education in the philosophy, approach, and disciplines of aerospace engineering, and to conduct research at the forefronts of a wide range of technologies critical to the future development of aerospace.

The aerospace community is unusual in its emphasis on advanced technology, and in its responsibility for large complex vehicles and systems which demand uniform excellence in engineering and management. It continually seeks to advance basic understanding of a wide range of physical phenomena, to conceive new devices and systems based on this understanding, and to carry them through the development process to practical use. It encompasses a wide range of talent, from basic researchers to managers of organizations employing thousands of engineers.

The MIT Department of Aeronautics and Astronautics is equally unusual in its commitment to providing education for and access to this broad range of opportunities in aerospace engineering. Its success in this endeavor is indicated by the large numbers of its alumni who are senior managers in government and in major aerospace firms, or in the forefront of basic research in the engineering sciences. The extensive involvement of its faculty with government and industry is a further measure of the Department's central role in the aerospace community.

The aerospace vehicle — be it a helicopter, commercial transport, satellite, or space shuttle — provides a focus for many aspects of aerospace engineering with which the Department deals. Throughout its teaching and research activities, the vehicles and the transportation systems of which they are key elements motivate and coordinate the instruction and research. The faculty is also alert to the applications of aerospace-derived technologies to other than aerospace uses, resulting in a myriad of couplings to the scientific and engineering research communities.

At the undergraduate level, the Department seeks to provide a broad introduction to aerospace engineering, together with thorough basic education in all of the disciplines critical to aerospace. The departmental program comprises: 1) Unified Engineering, an introductory subject taught cooperatively by a number of senior faculty members, covering all of the basic disciplines in an interrelated format as well as experimental and systems approaches; 2) a choice of Advanced Required Subjects and access to Electives providing greater depth in each disciplinary area; and 3) the Experimental Projects Laboratory, in which each

Undergraduate Study

student conceives and executes an individual experiment. In addition, undergraduates are encouraged to become involved in the research activities of the Department through the Undergraduate Research Opportunities Program. Research opportunities are outlined under Graduate Study.

The graduate teaching and research activities of the Department are strongly interwoven, since the 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.

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. 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.

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.

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 3.091 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 [2 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
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

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 [2 subjects can be satisfied from among 6.002, 8.03, 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
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; 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

*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 also listed in the subject description.

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 the 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 which permits an absence from MIT during 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 which 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 usually is 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 which 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 which 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 Emmett A. Witmer, Room 33-208, MIT, Cambridge, Massachusetts 02139, (617) 253-2279.

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	
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 also listed in the subject description.

Graduate Study

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	
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 prerequisties are also 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 which are concerned with material, energy, and information transfer and its 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. 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. Rotary wing aerodynamics and noise are interests of the Helicopter Rotor Acoustics Laboratory. 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 aggressively pursue 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 Aeroelastic and Structures Research Laboratory, 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 which can contain catastrophic failures, a large and a small chamber for the simulation of zero-g structural behavior, wind tunnels, and a blow down 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 of the lab 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 and Plasmadynamics 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 whose 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 which should include subjects in most of the divisions described above. In addition the student should obtain training in the disciplines which support systems analysis, such as probability and statistics, operations research, economics, and computer science, and should also maintain an awareness of the external disciplines which 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 examination is usually taken during the first year of graduate study in the Department, but not later than the third term. The examination seeks to measure the candidate's fundamental understanding of the principles underlying aerospace engineering and aptitude for engineering research.

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 exam is usually administered during the week after the initial date of registration in Graduate School. 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" 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.

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. A candidate is admitted to the Doctoral program upon passing the Doctoral Qualifying Examination. 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 area is tested by a written and an oral General Examination administered by the doctoral thesis committee after completion of the major 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 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 which 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 which 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.

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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 teaching, government, or management. Students interested in the various areas of graduate study in Chemical Engineering should consult the section on Graduate Study which follows.

The School of Chemical Engineering Practice, also described in detail in the graduate section, involves one term of work under the direction of 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 which 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. Freshmen who want an early initial exposure to chemical engineering should take 10.01 Engineering Concepts and Computer Methods.

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 10.01 Engineering Concepts and Computer Methods may be taken in the freshman year. If the subjects 10.13, 10.14, 18.03, and the additional required chemistry course (5.13, 5.62 or 7.05) 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 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 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:		150
One of the following two subjects:		
5.310	Laboratory Chemistry, 12; 5.12	
5.311	Introductory Chemical Experimentation, 12; 5.11	
	plus	
5.11	Principles of Chemical Science[1], 12	
5.12	Organic Chemistry I, 12; 5.11	
	plus	
10.01	Engineering Concepts and Computer Methods, 12	
10.13	Mass and Energy Processing, 12; *18.02*	
10.14	Chemical Engineering Thermodynamics, 9; 10.01, 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	
10.36	Process Design, 12; 10.302, 10.32	
10.37	Chemical Kinetics and Reactor Design, 9; 10.13, 10.301	
18.03	Differential Equations, 12; 18.02	

1
Students who use 5.11 to fulfill the General Institute Requirements in Chemistry must take 12 additional units of Unrestricted Elective.

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
10.19	Experimental Methods in Combustion and Heat Transfer, 12; 10.302, 10.37
10.63	High Technology Separations Laboratory, 12
10.66	Polymer Rheology Laboratory, 12; 10.301
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	Chemical Engineering Thesis, 12
20.002	Laboratory in Applied Biology, 15

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	**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.
**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 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.

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; 5.11	
	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	
7.05	General Biochemistry, 12; 5.12	
	plus	
10.01	Engineering Concepts and Computer Methods, 12	
10.13	Mass and Energy Processing, 12; *18.02*	
10.14	Chemical Engineering Thermodynamics, 9; 10.01, 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	

1
Students who use 5.11 to fulfill the General Institute Requirements in Chemistry must take 12 additional units of Unrestricted Elective.

Graduate Study

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
10.19	Experimental Methods in Combustion and Heat Transfer, 12; 10.302, 10.37
10.63	High Technology Separations Laboratory, 12
10.66	Polymer Rheology Laboratory, 12; 10.301
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	Chemical Engineering Thesis, 12
20.002	Laboratory in Applied Biology, 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.

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, Chemistry, and Applied Biological Sciences).

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 which 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, metallurgy, and others 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.

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 Professor William Deen, Graduate Registration Officer, Department of Chemical Engineering, Room 66-509, MIT, Cambridge, Massachusetts 02139, (617) 253-4535.

Department of Civil Engineering

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Professor of Civil Engineering
Head of the Department

Professors

Gregory Bert Baecher, Ph.D.
Professor of Civil Engineering

Mohsen Mohamed Baligh, Ph.D.
Professor of Civil Engineering

Rafael Luis Bras, Sc.D.
Professor of Civil Engineering

Oral Buyukozturk, Ph.D.
Professor of Civil Engineering

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

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
(On leave)

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
Director, Project Athena

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

Fred Moavenzadeh, Ph.D.
Professor of Civil Engineering
William E. Leonhard Professor of Engineering
Director, Technology and Development Program

Francois M. M. Morel, Ph.D.
Professor of Civil Engineering

Amedeo Rodolfo Odoni, Ph.D.
Professor of Civil Engineering and Aeronautics and Astronautics

Frank Edward Perkins, Sc.D.
Professor of Civil Engineering
Dean of the Graduate School

Daniel Roos, Ph.D.
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Director, MIT Center for Technology, Policy, and Industrial Development

Joseph Martin Sussman, Ph.D.
Professor of Civil Engineering
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Daniele Veneziano, Ph.D.
Professor of Civil Engineering

Robert Van Duyne Whitman, Sc.D.
Professor of Civil Engineering

Nigel Henry Moir Wilson, Ph.D.
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Associate Professors

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Harold Field Hemond, Ph.D.
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Eduardo Kausel, Ph.D.
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Victor C. Li, Ph.D.
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Dennis B. McLaughlin, Ph.D.
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Wallace Kendall Melville, Ph.D.
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Assistant Professor of Civil Engineering

Lorna Jane Gibson, Ph.D.
Assistant Professor of Civil Engineering

George Andrew Kocur, Ph.D.
Assistant Professor of Civil Engineering

Sue McNeil, Ph.D.
Assistant Professor of Civil Engineering

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Alexander Slocum, Ph.D.
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George Macomber Career Development Assistant Professor in Construction Management

Duvvuru Sriram, Ph.D.
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John T. Germaine, Ph.D.
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William J. LeMessurier, S.M.
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Hugo Perez La Salvia, Ph.D.
Ignacio Rodriguez-Iturbe, Ph.D.
Louis Shaffer, Ph.D.
Uri Shamir, Ph.D.

Department of Civil Engineering

(Course 1)

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 which 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 which 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 a special option in Engineering Systems and Computation.

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 undergraduate and graduate degrees to be received simultaneously.

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 which 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 which 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; 1.04, *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, 12; 1.04
1.60	Fluid Dynamics, 12; 1.05
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

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 which lead 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 Computations Option described later is one such program.

Programs leading to this degree are not accredited by the Accreditation Board for Engineering and Technology, an issue which 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.

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 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 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, 12
18.03	Differential Equations, 12; 18.02,
1.12	Computer Models of Physical and Engineering Systems, 12; 1.00, 18.02, 8.01

Engineering Science

1.04	Behavior of Physical Systems I, 12; 8.01, 18.02
1.05	Behavior of Physical Systems II, 12; 1.04, *18.03*

Engineering Systems and Computation

1.01J	Engineering Aspects of Economic Analysis, 12
1.03	Probability and Statistics, 12

plus four of the following five subjects:

1.02	Optimal Design of Engineering Systems, 12; 1.00
1.06	Stochastic Models, Reliability, and Simulation for Large-Scale Systems, 12; 1.00, 1.03
1.07	Engineering Applications of Artificial Intelligence 12; 1.00
1.08	Design of Automated and Robotic Systems, 12; 1.00
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: 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

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.

The degree requirements for this program are similar to Course I-A (ES&C Option), except there are seven required subjects (1.00, 1.12, 18.03, 1.04, 1.05, 1.01J, and 1.03), 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 whith, 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 option in Engineering Systems and Computation).

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.

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
- 1.05 Behavior of Physical Systems II, 12; 1.04, *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, 12; 1.04
- 1.60 Fluid Dynamics, 12; 1.05
- 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

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**
Total Units Required for the S.B. Degree	**180**

*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 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 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, 12
- 18.03 Differential Equations, 12; 18.02
- 1.12 Computer Models of Physical and Engineering Systems, 12; 1.00, 18.02, 8.01

Engineering Science
- 1.04 Behavior of Physical Systems I, 12; 8.01, 18.02
- 1.05 Behavior of Physical Systems II, 12; 1.04, *18.03*

Engineering Systems and Computation
- 1.01J Engineering Aspects of Economic Analysis, 12
- 1.03 Probability and Statistics, 12

plus four of the following five subjects:
- 1.02 Optimal Design of Engineering Systems, 12; 1.00
- 1.06 Stochastic Models, Reliability, and Simulation for Large-scale Systems, 12; 1.00, 1.03
- 1.07 Engineering Applications of Artificial Intelligence 12; 1.00
- 1.08 Design of Automated and Robotic Systems, 12; 1.00
- 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: **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.

Unrestricted Electives	**45**
Total Units Required for the S.B. Degree	**180**

*The degree requirements applicable to Classes that entered MIT prior to September 1985 can be obtained from the Department.

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 which 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 for 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, and analytical mechanics.

The major areas of research and teaching in the Constructed Facilities Division are:

Geotechnical Engineering. The graduate program in geotechnical engineering provides an understanding of advanced mechanical and geological principles that control the behavior of soil and rock and familiarizes the student with geotechnical analysis and design techniques and with the incorporation of geology in planning of civil engineering projects.

The teaching program offers comprehensive treatment of theoretical soil mechanics and soil properties, engineering geology and rock mechanics, exploration and instrumentation, earth dams and foundations, and advanced subjects in soil dynamics, reliability, and computer-aided engineering. The major areas of research are: soft-ground construction, earthquake engineering, underground construction, stability of earth dams and natural slopes in soil and rock, behavior of soils under cyclic loading, pile foundations, applications of probability and decision theory, mining geotechnics, and *in-situ* testing — especially for offshore exploration.

Structural Design and Analysis. A comprehensive treatment of the behavior of complex steel and concrete structures is the key element of the structural design and analysis program. Exposure to design procedures is provided by a set of laboratory subjects dealing with important design issues for buildings, bridges, and offshore structures. Additional study areas include structural analysis, analytical mechanics, structural dynamics, numerical modeling, structural loads, offshore structural engineering, structural mechanics for nuclear power facilities, and structural reliability.

A cooperative effort within the School offers a special opportunity to study structural mechanics for nuclear power engineering. Students studying this and other aspects of mechanics and materials may take advantage of subject offerings in all departments of the School.

The research program includes projects in the following areas: earthquake engineering, statistically based loading and serviceability criteria for design, three-dimensional models for failure of concrete, computational strategies for complex concrete structures, and offshore structures.

Engineering Risk Assessment is important for civil engineering projects, since uncertainties of site characterization, loading, and construction materials are large. The academic program of the Division has been designed to provide in-depth exposure to probability theory, statistics, modeling with random functions, and risk-based decision methods. Disciplinary subjects are complemented by application-oriented subjects in structural reliability, uncertainties in geotechnical engineering, and risks in construction.

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 are 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 following laboratories are associated with the Division:

The Geotechnical Engineering Research Laboratory conducts applied and fundamental research on the engineering properties of soil and rock, develops new methods of analysis, and measures and evaluates the field performance of structures during and after construction. The primary objective is evaluating and improving methods for predicting the behavior of constructed facilities.

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 which are then tested for verification of the design.

The Materials Laboratory is both an educational and a research facility. It helps students relate the mechanical properties of construction materials to their composition. Current research includes mechanical behavior of concrete and asphaltic composites under various environmental conditions, and development of new composite materials for construction.

The REMERGENCE Laboratory is a joint effort of the Departments of Civil and Mechanical Engineering in the Resource Extraction, Materials, Energy, Reservoir, Geotechnical, ENvironmental, and Construction Engineering areas. The laboratory provides testing facilities for experimentation on geologic and construction materials both for teaching and research.

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 which 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: railroad operations 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; 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 and Coastal 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 and offshore structures, estuary and coastal circulation and water quality, energy extraction from waves and the ocean thermal gradient, 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 hydrologic processes in the surface and ground water regimes. Particular attention is given to the integration of hydrologic criteria and optimization methods for multi-objective urban and river basin development schemes with environmental, economic, and public policy issues. Opportunities may exist for summer fieldwork in developing countries. Related subjects in probability and systems methodology are also offered.

Water Quality Control, Aquatic Science, and Environmental Engineering. Major areas of activity, including possibilities for interdisciplinary work, are: environmental fluid mechanics, aquatic chemistry and biology, limnology, and the environmental impact of energy development and the fate of pollutants in various kinds of natural water bodies and groundwater. Emphasis is on the integration of hydrodynamic and hydrothermal transport and mixing processes with biogeochemical transformation processes including effects of heavy metals and hydrocarbons.

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, 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 to study aquatic biological and chemical interactions.

Center for Construction Research and Education

The Center was established to provide closer ties with the construction industry, and reflects a major commitment by the Department to advances which can help the industry meet the opportunities and challenges for the next several decades.

The Center provides a specific focus within the Department for students, faculty, and industry personnel to interact and collaborate on a wide range of projects of particular interest to the construction industry. For the student preparing for a career in the construction industry, the Center offers advanced degree programs, internships and summer jobs, and industry-sponsored thesis research opportunities.

The Center currently offers an integrated graduate degree program in **Construction Engineering and Management.** As construction problems become more complex, the industry must control, more reliably than ever, time, cost, and quality, cope with new technologies and means of production, and be concerned with increasingly complex human relations. There is increasing interdependence between the inception, feasibility, determination, design, and production phases of development, with a corresponding need for greater sophistication in planning, organization, and management.

In addressing this need, the program in Construction Engineering and Management encompasses the totality of activities from the initial needs analysis for a facility, through economic and technical feasibility studies, environmental and social impact analyses, design, construction, and operation.

The research activities of the Center are highly collaborative and focus on: management (at the industry, and project levels); resources (labor, materials, equipment, and finance); and technology (innovation, productivity, adaptation, and transfer). Major research programs include: the role of construction in energy; technology and productivity; rebuilding America's infrastructure; management of superprojects; computer applications in construction; construction and socio-economic development; and construction industry competitiveness in the world market.

The Center promotes and coordinates a number of liaison activities with the construction industry, which provides ways for industrial representatives to share their perspectives on the educational and research needs of industry.

Computer Facilities

The Department has a computer facility devoted to Computer-Aided Design in the Architecture-Engineering-Construction disciplines. This facility contains Apollo Computers graphic workstations networked together with a file server/computer server processor. It also contains a number of microcomputers and major software packages for bridge, highway, and building design and drafting for use in academic subjects and research activities.

The Department also participates in the Joint Computer Facility with several other departments to provide DIGITAL VAX 11/780 and other computational services for use by students and faculty in the department's academic and research programs.

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 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 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.

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Edward J. Moriarty, S.B.
Marilyn Andrea Pierce
Helen V. Schwartz, M. S.
Edward S. Shaw, B.S.
Manuel L. Silva, A.E.E.
Horace McNutt Smith, Jr., B.A.

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Nathaniel Isaac Durlach, M.A.
Dennis H. Klatt, Ph.D.
Robert Harmon Rediker, Ph.D.

Principal Research Scientist

John J. Guinan, Ph.D.

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Kuang-yi Huang
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Research Affiliates

Kenneth J. Germeshausen, S.B.
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Vernon E. MacRoberts
Peter W. Mui, S.B.
Robert Poss, M.D.
Mitchell R. Swartz, M.D.

Postdoctoral Associates

Sue Ann Bidstrup, Ph.D.
Jean-Louis Lievin, Ph.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

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.
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Robert Louis Kyhl, Ph.D.
Professor of Electrical Engineering, Emeritus

Yuk-Wing Lee, Sc.D.
Professor of Electrical Engineering, Emeritus

Joseph Carl Robnett Licklider, Ph.D.
Professor of Electrical Engineering, Emeritus

Parry Moon, S.M.
Associate Professor of Electrical Engineering, Emeritus

John Francis Reintjes, M.E.E.
Professor of Electrical Engineering, Emeritus

Walter Alter Rosenblith, Ing. Rad.
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Provost, Emeritus
Professor of Communications Biophysics, Emeritus

Claude Elwood Shannon, Ph.D.
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Louis Dijour Smullin, S.M.
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Arthur Robert Von Hippel, Ph.D.
Institute Professor, Emeritus
Professor of Electrophysics, 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, some of which 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 or 20.002 Laboratory in Applied 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	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	
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 Electrical 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, linear and modern algebra, and theory of computation. Restricted electives allow the student to choose additional subjects in computer systems or language implementation, algorithms, 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 Electrical 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:		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, 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	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; 6.001, 8.01, 18.02	
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		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.

**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, John A. Tucker, 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	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
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	366

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	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; 6.001, 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 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 which 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 which 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 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 and Doctor of Science

The general requirements for the degree of Doctor of Philosophy or Doctor of Science are given in Chapter IV. Only students who have shown promise of performing truly creative work are encouraged to study for the doctoral degree. 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 beginning graduate work in the Department are required to qualify first for the Master of Science or the Electrical Engineer degree; the quality of the thesis submitted for these degrees is a major component in the decision to qualify a student for the doctoral program. Students who have completed a Master's degree elsewhere are required to submit evidence of research accomplishment before being qualified for the doctoral program.

All regular graduate students who intend to enter a doctoral program are required to complete a written examination early in their graduate study. For students not specializing in computer science, the examination occurs in January of their first year of graduate study and is designed to explore students' undergraduate preparation for graduate study. For students specializing in computer science, the examination occurs in January of their second year of graduate study and is designed to evaluate student preparation in those areas of computer science which the faculty believe to be fundamental to graduate study in this field at MIT.

The General Examination consists of the written examination described above and two oral examinations. One oral examination is normally taken in the third term of graduate study and the other in the fifth term. When the doctoral thesis research is completed, a thesis examination is held. A Minor Program is required by the Department and must have departmental approval.

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 Horace M. Smith, Jr., Room 38-444, MIT, Cambridge, Massachusetts 02139, (617) 253-4605.

Department of Materials Science and Engineering

Merton Corson Flemings, Sc.D.
Toyota Professor
Head of the Department

Professors

Benjamin Lewis Averbach, Sc.D.
Professor of Materials Science

Robert Weierter Balluffi, Sc.D.
Professor of Physical Metallurgy

Michael Berliner Bever, Dr.Jur., M.B.A., Sc.D.
Professor of Materials Science and Engineering, Emeritus
Senior Lecturer

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

Robert Louis Coble, Sc.D.
Professor of Ceramics, Emeritus
Senior Lecturer

Morris Cohen, Sc.D., D.Tekn.
Institute Professor, Emeritus
Professor of Materials Science and Engineering, Emeritus
Senior Lecturer

John Frank Elliott, Sc.D.
Professor of Metallurgy
Director, Mining and Mineral Resources Research Institute
American Iron and Steel Institute Distinguished Professor

Harry Constantine Gatos, Ph.D., Sc.D. (honoris causa)
Professor of Electronic Materials and Molecular Engineering
(On leave, fall)

Nicholas John Grant, Sc.D.
Professor of Metallurgy, Emeritus

Linn Walker Hobbs, D.Phil.
Professor of Ceramics

Keith Huber Johnson, Ph.D.
Professor of Materials Science
(On leave, spring)

William David Kingery, Sc.D., Ph.D. (honoris causa)
Kyocera Professor of Ceramics

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
(On leave, spring)

Koichi Masubuchi, D.Eng.
Professor of Materials Science and Ocean Engineering

Frederick Jerome McGarry, S.M.
Professor of Polymer Engineering and Civil Engineering
Director of Summer Session

Walter Shepherd Owen, Ph.D.
Professor of Physical Metallurgy, Emeritus
Senior Lecturer

Regis Marc Noel Pelloux, Sc.D.
Professor of Materials Engineering

Nicolaos S. Platakis, Ph.D.
Professor of Materials Science (Visiting)

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

Donald Robert Uhlmann, Ph.D.
Cabot Professor of Ceramics and Glass

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

Ioannis Vassiliou Yannas, Ph.D.
Professor of Polymer Science and Engineering

Associate Professors

Samuel Miller Allen, Ph.D.
Associate Professor of Physical Metallurgy

Thomas Waddy Eagar, Sc.D.
Associate Professor of Materials Engineering

Terry Arthur Ring, Ph.D.
Associate Professor of Minerals Engineering

David Kaye Roylance, Ph.D.
Associate Professor of Materials Engineering

Donald Robert Sadoway, Ph.D.
Associate Professor of Materials Engineering

Gary Edmund Wnek, Ph.D.
ARCO Associate Professor of Polymers

Gregory John Yurek, Ph.D.
Associate Professor of Metallurgy

Assistant Professors

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IBM Assistant Professor of Polymers

David Albert Rudman, Ph.D.
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R. Erik Spjut, Ph.D.
John Chipman Assistant Professor of Chemical Process Metallurgy

Carl Vernette Thompson III, Ph.D.
Mitsui Career Development Professor of Contemporary Technology

Adjunct Professor

Lionel C. Kimerling, Ph.D.
Adjunct Professor of Electronic Materials

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Joseph Tibor Blucher, Sc.D.

Technical Instructor

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John P. Cronin, Ph.D.
Mark Eberhart, Ph.D.
Frank R. Field III, Ph.D.
Daniel Goldschmidt, Ph.D.
Ernesto M. Gutierrez, Ph.D.
Enrique J. Lavernia, Ph.D.
Min-Long Lin, Ph.D.
Jean-Luc Marchand, Ph.D.
Pradnya V. Nagarkar, Ph.D.
Aleksandar G. Ostrogorsky, Ph.D.
Peter C. Searson, Ph.D.
Carl D. Sorensen, Ph.D.
Steven J. Thorpe, Ph.D.
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Kijoon Yu, Ph.D.

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Roland P. Carreker, Ph.D.
Rosemary A. Cartwright, D.Phil.
Arlete Cassanho, Ph.D.
Young Chang Chu, Ph.D.
Amjad H. Dilawari, Ph.D.
Leonard E. Dolhert, Ph.D.
Anuradha M. Ghemawat, M.S.
Andrzej Hennel, Ph.D.
Akihiro Hishinuma, M.S.
Keizo Hosoya, M.S.
Chen-Feng Kao, Sc.D.
Hongshi Kong, M.S.
Genrich L. Krasko, Ph.D.
Hua Li, B.S.
Jin Ke Li, B.S.
Chengtian Lin, M.S.
Setsuo Mishima, M.S.
Vivek V. Nagarkar, Ph.D.
Yasunobu Ogata, M.S.
Cheng Jien Peng, B.S.
Kazimierz Przybylski, Ph.D.
Shinichi Sasayama, M.S.
Lian Shen, Ph.D.
Marek Skowronski, Ph.D.
Tetsuya Suganuma, M.S.
Shu-Wei Sun, M.S.
Jufen Tan, M.S.
Gimtong Teowee, B.S.
Yaotang Wu, Ph.D.
Xiwen Xie, B.S.
Kuihong Yao, B.S.

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Yin-Lin Xie, B.S.

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Richard D. Vera, M.A.

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Senior Lecturer

Morris Cohen, Sc.D., D.Tekn.
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Carl Frederick Floe, Sc.D.
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Professor of Metallurgy, Emeritus

Frederick Harwood Norton, Sc.D.
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 Technology and Science, 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 which 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 which 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 which 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.

Students who decide before the sophomore year to study materials science and engineering can facilitate their later progress by including 18.03, 3.00, and 3.01 (or equivalents) in their second-year subjects. The third and fourth years may then be devoted to study, in some depth and with adequate preparation, of areas such as ceramics, metallurgy, polymers, and electronic materials through appropriate use of upperclass elective time.

Some students, on the other hand, do not wish to make a choice of major until their junior year or may wish to use their upperclass elective time to the fullest possible extent in the second year. Generally, it is possible to complete the Departmental Program and Institute Requirements in two more years, especially if one of the second-year Science Distribution subjects is in mechanics of solids.

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; 3.01**, 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]		57-60
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	
Electronic Materials		
3.084	Electronic Materials Project Laboratory, 9; 3.147J	
3.146	Electronic Materials, 9; 3.10	
3.147J	Microelectronics Processing Technology, 12; 3.185	
3.15	Electrical, Optical, and Magnetic Materials and Devices, 9; *3.10*	

1
Substitution of similar subjects may be permitted by petition.
2
Students can elect up to 15 units.

Restricted Electives (continued)		
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		
3.061J	Structure and Properties of Polymers, 9; 3.091**, 3.00	
3.062	Polymer Chemistry, 9; 3.091**, 3.10	
3.064	Polymer Engineering, 9; 3.11, 3.185	
3.065	Polymer 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 also 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 which 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.

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, 3.082, and 3.084; 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.

The program is particularly attractive to students who wish to study for the combined S.B.-S.M. degree, requiring five years for completion. Such students, if they satisfy the requirements, apply for admission into the graduate school during the senior year. They then complete two further consecutive work terms. A single thesis, which is ordinarily based on the industrial experience, suffices for the combined degrees.

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. R. Sadoway, Room 8-109, MIT, Cambridge, Massachusetts 02139, (617) 253-3487.

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; 3.01*, 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	
Electronic Materials		
3.084	Electronic Materials Project Laboratory, 9; 3.147J	
3.146	Electronic Materials, 9; 3.10	
3.147J	Microelectronics Processing Technology, 12; 3.185	
3.15	Electrical, Optical, and Magnetic Materials and Devices, 9; *3.10*	

Restricted Electives (continued)		
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		
3.061J	Structure and Properties of Polymers, 9; 3.091*, 3.00	
3.062	Polymer Chemistry, 9; 3.091*	
3.064	Polymer Engineering, 9; 3.11, 3.185	
3.065	Polymer Laboratory, 12; 3.081, 3.11	
Unrestricted Electives		**up to 48**
Total Units Required for the S.B. Degree		**360**

* Alternate prerequisites are also 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 of 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 which include 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 and 6.732J Physics of Solids II.

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 which 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 3.40 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 which 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, 3.93 Materials Science of Polymers, and 3.961 Polymer Synthesis and Properties or 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 which 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 which 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.

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 B. J. Wuensch, Room 8-303, MIT, Cambridge, Massachusetts 02139, (617) 253-3329.

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Department of Mechanical Engineering

(Course 2)

Engineering is a creative profession concerned with the combining of 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 accoustical 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 generators and preservation of living biomaterials by freezing.

Fibers and Polymers Laboratories — fiber physics, textile processing dynamics, polymer engineering, and the development of biological materials such as artificial skin.

Fluid Mechanics Laboratory — research areas which reflect the variety of applications of fluid mechanics: nuclear power plant safety; environmental protection; cardiovascular, pulmonary, and ocular flow systems; computational fluid dynamics; laminar stability, turbulence, and oscillatory flows.

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 54 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.

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.

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
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:		138
2.01[5]	Mechanics of Solids, 12; 8.01, 18.02	
2.02[5]	Introduction to Systems Dynamics, 12; 8.01, 18.02	
2.03J	Dynamics, 12; *2.01*, 2.02, 18.03	
2.20[5]	Fluid Mechanics, 12; 18.02, *18.03*	
2.30	Mechanical Behavior of Materials, 15; 2.01, *2.86*	
2.40[5]	Thermodynamics, 12; 8.02, *18.03*	
2.671[5]	Measurement and Instrumentation, 9; 2.02	
2.672	Project Laboratory, 6; *2.20*, *2.40*, 2.671	
2.70[5]	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[5]	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.		
Group A		
2.06J	Mechanical Vibration, 12; 2.03J**	
2.14	Control System Principles, 12; 2.02	
2.21	Fluid Mechanics of Power and Propulsion, 12; 2.20, *2.40*	
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	
15.001	Managerial Economics, 12	
Units in Departmental Program that also satisfy the General Institute Requirements		(36)
Unrestricted Electives[4]		54
Total Units Required for the S.B. Degree Beyond the General Institute Requirements		180

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.

4
The Department recommends that students elect an introductory digital-computing subject (such as 2.10) as early as possible in their programs.

* 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 which 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.

5
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.

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 which 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 which 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, 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:		**138**
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, *2.86*	
2.40	Thermodynamics, 12; 8.02, *18.03*	
2.671	Measurement and Instrumentation, 9; 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, 2.31 or 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.

Graduate Study

Restricted Electives (continued)	
Group A	
2.06J	Mechanical Vibration, 12; 2.03J*
2.14	Control System Principles, 12; 2.02
2.21	Fluid Mechanics of Power and Propulsion, 12; 2.20, *2.40*
2.22	Computational Methods in Engineering, 12; 18.03, 2.10
2.34J	The Mechanics of Fracture, 12; 2.31 and 2.32 or 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	Managerial Economics, 12
Unrestricted Electives	54
[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.

The Department provides opportunities for graduate work leading to the Master of Science in Mechanical Engineering, the Master of Science, the Master of Science in Textile Technology, the Mechanical Engineer, the Materials Engineer, the Environmental Engineer, the Doctor of Science, and the Doctor of Philosophy.

Entrance Requirements for Graduate Study

Students beginning graduate study in mechanical engineering usually have received the equivalent of a Bachelor's degree in mechanical engineering at a recognized engineering school; however, in many cases they have had their undergraduate preparation in some other branch of engineering or science. Generally, their background includes preparatory studies in some or all of the following areas: applied mechanics, fluid mechanics, dynamics, thermodynamics, electric circuits, electromagnetic fields, and materials. The Department requirements for admission are not specific, since capable students with a more general preparation have the opportunity to establish their background in mechanical engineering by taking the most advanced undergraduate subjects which their abilities and preparation permit.

The Department requires that all incoming graduate students must demonstrate, by taking a test, satisfactory English writing ability, or else, before receiving their degree, successfully complete remedial training.

Fields of Graduate Study

As a guide to graduate students, the various avenues for forming a program of study and thesis research are described below.

Engineering Science. Some students elect to concentrate their studies in one or more of the various engineering sciences. Subjects in the engineering science areas are listed in Chapter VIII, grouped under the following series of numbers and headings:

2.0-	Mechanics, Dynamics, and Acoustics
2.1-	System Dynamics and Control
2.2-	Fluid Mechanics and Combustion
2.3-	Materials
2.4-	Thermodynamics and Statistical Mechanics
2.5-	Heat and Mass Transfer
2.8-	Manufacturing
2.9-	Polymers and Fibers

Professional Areas. The eight fields listed next represent some possible professional areas of concentration in graduate study in mechanical engineering. They are described more fully in the introduction to this Department. In addition to subjects offered by the Department in each of these areas, graduate subjects are offered by other departments as well. Lists of available subjects in each area may be obtained from the Department.

Energy Conversion and Conservation — problems of energy conversion and conservation, including cryogenic applications.

Environmental Engineering — problems of air, water, and land pollution, and of conserving material and energetic resources.

Biomedical Engineering — the application of engineering techniques to the advancement of human health, including diagnosis, therapy, health care systems, and development and production of devices used in the medical field.

Manufacturing and Materials Processing — manufacturing processes, design and control of process machinery, process optimization, and computer-controlled automation. Textiles, polymer and metals processing.

Transportation — transportation technology and systems including structures, power and propulsion, automation and control.

Computers and Control — the application of computers to problem solving and design and the use of automatic controls for processes and devices.

Mechanics and Materials — acoustics and noise control, continuum mechanics, numerical computation, techniques of solving problems of solid mechanics. Physical and microstructural bases of mechanical behavior of engineering materials and its modeling.

Design — problem solving applied to the creation of, principally, hardware involving any of the engineering disciplines.

Graduate Core Subjects

The Department offers the following series of basic core subjects which cover the major mechanical engineering disciplines, expose students to applications of the disciplines and to the modeling of real engineering situations, and bring the fields to the starting points of their more advanced and specialized branches. A selection of these subjects represents excellent preparation for more advanced work and for the doctoral qualifying examination.

2.032	Dynamics (A)
2.083	Applied Elasticity (A)
2.151	Advanced System Dynamics and Control (A)
2.25	Advanced Fluid Mechanics (A)
2.301	Advanced Mechanical Behavior of Materials (A)
2.451J	General Thermodynamics I (A)
2.55	Advanced Heat Transfer (A)
2.731	Advanced Engineering Design (A)

Master of Science in Mechanical Engineering and Master of Science

The general requirements for these degrees are given in Chapter IV with the provision that the 66 required units must be taken during the two regular terms or during the summer term.

To qualify for the Master of Science in Mechanical Engineering a student must have had, or take while at MIT, two terms of advanced mathematics and must take one course in each of two areas of engineering science. Students not satisfying this requirement are awarded the Master of Science without specification of field. The above requirements apply to students who have an S.B. degree in mechanical engineering. Other students may be required to take additional subjects to complete their background in mechanical engineering.

Further description of the requirements for these degrees may be obtained from the Graduate Registration Office.

Master of Science in Technology and Policy

Students interested in applying their mechanical 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 courses in advanced technology in the particular field of the student's choosing with courses in economics, systems analysis, political science, and law. General requirements and application procedures are described in Chapter VI.

Mechanical Engineer

For those who desire preparation for engineering practice at a professional level beyond the Master of Science, the Mechanical Engineer is offered. The degree requires at least one year of study beyond the Master of Science. The program is centered around the application of engineering principles to advanced development problems and includes an applications-oriented thesis. The general requirements for the degree are given in Chapter IV; a detailed description of the Mechanical Engineer program may be obtained from the Graduate Registration Office.

**Joint MIT-Woods Hole Oceanographic Institution Program
Course II-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.

Doctor of Philosophy and Doctor of Science

Admission to the doctoral program is granted only after the candidate has passed a rigorous qualifying examination, which is taken no later than the end of three regular terms after arrival or completion of the Master's degree. The requirements for the doctoral degree include a program of advanced study, a minor program, and a thesis in the field of mechanical engineering.

The program of advanced study and research may be selected in any field of science or engineering approved by the Department Committee on Graduate Studies. While no fixed number of units is prescribed, the usual program includes a substantial number of courses in the student's principal area of interest. These, along with the minor program, usually require an additional four terms of work beyond the Master's degree. The major and minor programs must be approved by the student's doctoral committee and the components must have the *advance* approval of the Graduate Office of the Department of Mechanical Engineering.

For the thesis, each candidate undertakes a program of research which contributes significantly to the major field of interest. This contribution may be analytical, experimental, or design knowledge. The program of advanced study and the thesis are under the supervision of a thesis supervisor and a doctoral committee selected by the student and the supervisor. The doctoral committee makes an annual evaluation of the candidate's progress and conducts a final examination based on the thesis. Successful completion of the doctoral program usually requires at least two years of registration beyond the master's degree.

Doctor of Philosophy in Biomedical Engineering

The Department has an extensive program of research and teaching in biomedical engineering. Qualified students registered in the Department may pursue programs for the regular Master's degree and doctorate awarded by the Department, with a focus in biomedical engineering, or, alternatively, may elect an interdepartmental doctoral program in biomedical engineering (administered by the Committee on Biomedical Engineering) which is described in Chapter VI.

Fellowships and Assistantships

A large number of research assistantships and a few fellowships and teaching assistantships are available to incoming students. These appointments and awards provide adequate financial support for both tuition and living expenses. In practically all cases the thesis research is done as an integral part of the work associated with the research assistantship or fellowship. Application for these appointments and awards is made by checking the appropriate boxes on the application form for admission. Students are not considered for awards until they are assured of admission to the graduate school.

Inquiries

Additional information concerning academic and research programs, admissions, financial aid, etc., may be obtained by writing to Leslie Regan, Mechanical Engineering Graduate Registration Office, Room 1-106, MIT, Cambridge, Massachusetts 02139, (617) 253-2291.

Department of Nuclear Engineering

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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

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Professor of Nuclear Engineering and Physics

Jeffrey Philip Freidberg, Ph.D.
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Michael Warren Golay, Ph.D.
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Ford Professor of Engineering
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Mujid Suliman Kazimi, Ph.D.
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David C. Aldrich, Ph.D.
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John H. Hopps, Jr., Ph.D.
William E. Vesely, Ph.D.
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Chul H. Cho, 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 50 percent. In the United States it is over 13 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 engineering 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 (22.010 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: 1.04, 2.01, or 8.06 for strength of materials (Engineering Principles I); 1.60, 2.20, 8.263, or 10.301 for fluid mechanics (II); 2.40, 3.00, 6.018, or 8.08 for thermodynamics (III); 2.51 or 10.302 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: 20.002 or 22.09 for laboratory; 22.021 for applied physics; and 22.04, 7.53, 7.51 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 operations of light-water reactor plants and other fission reactor plant concepts, 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 Departmental 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.

[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 which 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 Departmental 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**

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 which includes the core subjects General Health Physics, Nuclear Measurements Laboratory, 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 radiopharmaceutical 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 speciality 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") which 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 4,000 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, tuition awards, 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 the 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

Martin Aaron Abkowitz, Ph.D.
Professor of Ocean Engineering

Arthur Bernard Baggeroer, Sc.D.
Professor of Ocean Engineering and Electrical Engineering
MIT Director, MIT/WHOI Joint Program in Oceanography and Oceanographic Engineering

Michael J. Buckingham, Ph.D.
Professor of Ocean Engineering
(Visiting)

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
(On leave, fall)

Ernst Gabriel Frankel, Ph.D.
Professor of Marine Systems

Clark Graham, Ph.D.
Professor of Naval Architecture

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

Jerome H. Milgram, Ph.D.
Professor of Naval Architecture

John Nicholas Newman, Sc.D.
Professor of Naval Architecture

J. D. Nyhart, J.D.
Professor of Ocean Engineering and Management

John Kim Vandiver, Ph.D.
Professor of Ocean Engineering
Director, Experimental Study Group
Associate Chairman of the Faculty

Tomasz Wierzbicki, Sc.D.
Professor of Applied Mechanics

Associate Professors

Judith Tegger Kildow, Ph.D.
Associate Professor of Ocean Policy
(On leave)

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

Michael Stefanos Triantafyllou, Sc.D.
Associate Professor of Ocean Engineering
(On leave, fall)

Assistant Professors

Dale George Karr, Ph.D.
Assistant Professor of Ocean Engineering
Henry L. Doherty Professor in Ocean Utilization

Amiram Moshaiov, Ph.D.
Assistant Professor of Ocean Engineering

Nicholas Marinos Patrikalakis, Ph.D.
Assistant Professor of Ocean Engineering

Dick Kau-Ping Yue, Sc.D.
Assistant Professor of Ocean Engineering

Senior Lecturers

David Valentine Burke, Ph.D.

Dean Alden Horn, Nav.E.

Harry A. Jackson, B.S.
(Visiting)

William S. Pellini, B.S.
(Visiting)

Willard Franklin Searle, Jr., Nav.E.
(Visiting)

Lecturers

Howard M. Bunch, M.B.A.

Damon Ellis Cummings, Ph.D.
(Visiting)

Michael S. Drooker, Ocean E.

Leonard Grantner, D.Eng.Sc.

Maurice M. Sevik, Ph.D.

Paul Whitney Sparks, B.S.

Benjamin Whang, Ph.D.

Charalambos Ziogas, Ph.D.
(Visiting)

Administrative Officer

Patricia A. LeBlanc-Gedney, B.S.

Postdoctoral Associates

Spyridon A. Kinnas, Ph.D.
Andrew J. Langley, Ph.D.

Research Engineers

Michael S. Drooker, Ocean E.
Sumner Dean Lewis, B.S.

Visiting Scientists

Jean-Luc Guermond, Ph.D.
Wlodzimierz Abramowicz, Ph.D.

Visiting Research Associate

Jennie Claire Myers, S.M.

Research Specialist

Ysabel Mejia

Professors Emeriti

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)

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, which include 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.

Undergraduate Study

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]		138
One of the following three subjects:		
2.02	Introduction to Systems Dynamics, 12; 8.01, 18.02	
6.003	Signals and Systems, 15; 6.002, 18.03 or 18.06	
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; 1.05 or 2.20	
13.10J	Introduction to Structural Mechanics, 12; 2.01 or 16.004	
13.40	Introduction to Computer-Aided Ocean Engineering Design, 12; 2.01	
13.73	A Survey of Ocean Engineering, 2	
13.700-13.709	Special Problems in Ocean Engineering, 10	
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:[4,5]		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) 253-6823.

*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
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
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.

5
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]		138
One of the following three subjects:		
2.02	Introduction to Systems Dynamics, 12; 8.01, 18.02	
6.003	Signals and Systems, 15; 6.002, 18.03 or 18.06	
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; 1.05 or 2.20	
13.10J	Introduction to Structural Mechanics, 12; 2.01 or 16.004	
13.40	Introduction to Computer-Aided Ocean Engineering Design, 12; 2.01	
13.73	A Survey of Ocean Engineering, 2	
13.700-13.709	Special Problems in Ocean Engineering, 10	
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:[4,5]		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		54
Total Units Required for the S.B. Degree		360

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.

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.

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
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.

5
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.

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).

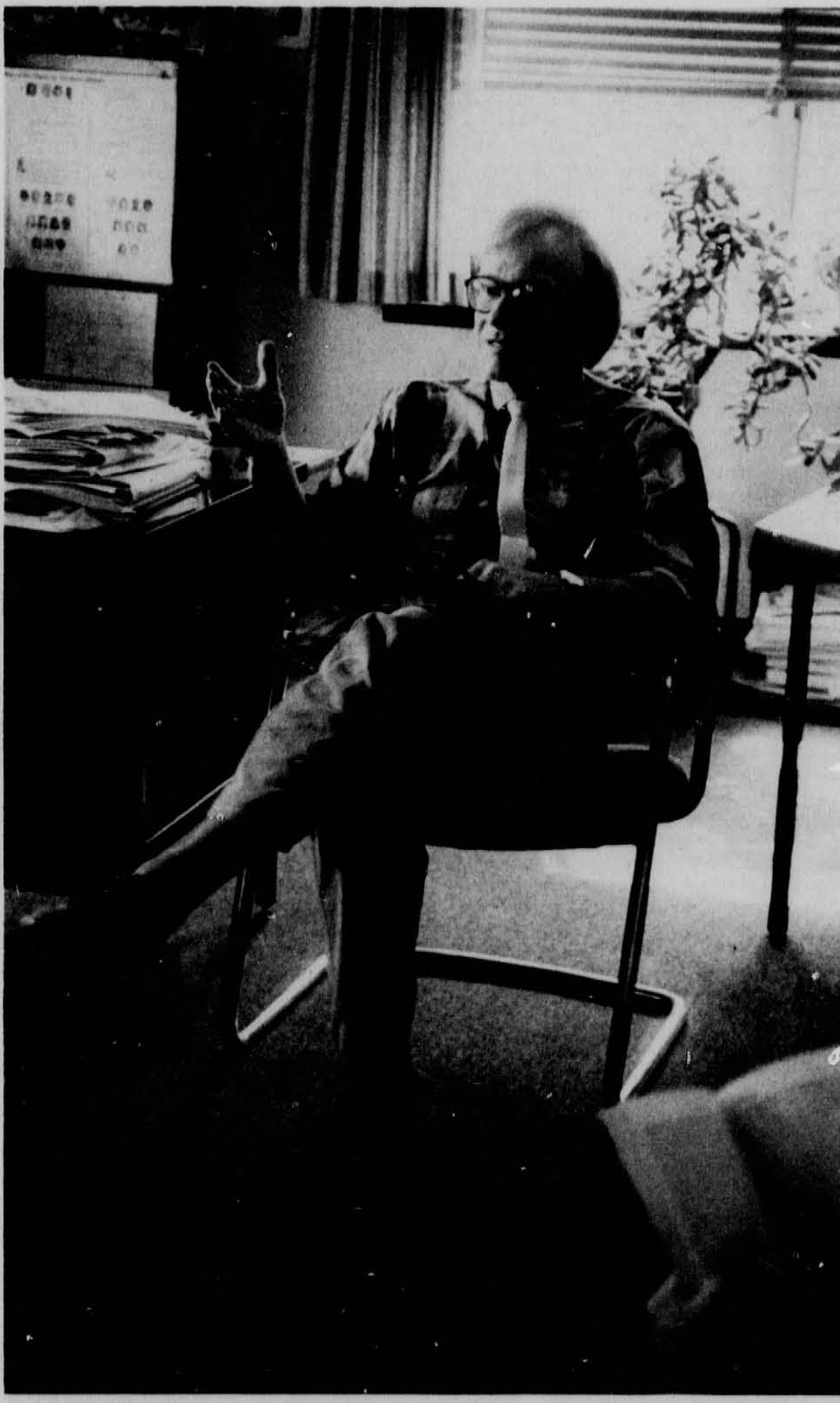
Prospective students are invited to communicate with the Department regarding any of these educational and financial opportunities. Applications for the Society of Naval Architects and Marine Engineers Graduate Fellowships, Office of Naval Research, and National Science Foundation fellowships are made 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, and the Center for European Studies at Harvard. Some of the graduate programs stress the use of mathematical and computer-oriented skills, but many doctoral theses are concerned with non-quantitative 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. In the field of communications, for example, there are many interdisciplinary projects, some involving collaboration among linguistics, philosophy, and psychology, which all have a special interest in cognitive science, and others involving political science and various branches of engineering. The Department of Economics and the Sloan School of Management cooperate

Special and Interdisciplinary Programs in Humanities and Social Science

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 does not undertake graduate training, but does offer a number of undergraduate degree programs. Through Course XXI, students may major in one of the humanistic disciplines (e.g., history, literature, anthropology, 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, Program 1) 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.

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 literature, foreign languages, archaeology and anthropology, history, music, drama, 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 and humanities.

The School's commitment to this view finds expression in a substantial Program in Science, Technology, and Society. This Program, which has both educational and research objectives, is concerned with the human consequences of scientific and technological advances.

To stress this new development is not to imply that MIT must emphasize science and technology in all its offerings in the humanities and social sciences. Ample room will remain for more or less conventional majors in economics, political science, philosophy, history, literature, foreign languages, anthropology, and music. Students will continue to demand the best in the humanities and social sciences as they demand the best in science and engineering. However, the emphasis will continue to be on making MIT undergraduate education something quite distinctive.

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 Undergraduate Office, Room 14N-409, (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 humanistic part of a **joint degree program** (Course XXI-E or XXI-S). 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. It is also possible for a student to work out a full major in American Studies. See Degree Program Requirements under the Department of Humanities.

Coordinator of American Studies for 1986-87 is Professor Arthur Kaledin, Room 14N-309, 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, Anthropology/Archaeology, and Traditions and Texts. 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 both for itself, in its uniqueness, and as an object of specifically 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 1986-87 is Professor Richard M. Douglas, Room 14N-417, 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 who teach 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 which MIT offers in dramatic literature, theatre arts, and dance, please contact Dr. Robert N. Scanlan, Room W16-108, 253-2908, or the Humanities Undergraduate Office, 14N-409, 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 organized in three categories of subjects: 1) those devoted exclusively to film (which emphasize the historical and artistic perspectives of the liberal arts); 2) those concerned primarily with television and mass communications (which center on the political, ideological, and policy-oriented perspectives of the social sciences); 3) those which use both perspectives in comparing film and media forms of story-telling and communication with their ancestors in older cultures and with the forms of other contemporary technologies. Collateral subjects in several national literatures, in anthropology, and in Science, Technology, and Society (STS), are particularly relevant in this group.

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; the Research Program on Communications Policy, which conducts seminars and research on the mass media; and the News Study Group, which archives and analyzes public affairs and news broadcasting. 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 coordinator of Film and Media Studies for 1986-87 is Professor David Thorburn, Room 14N-335, 253-6950.

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 humanistic 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 1986-87 is Professor Peter Smith, Room E53-365, 253-4430.

Psychology

Psychology is represented at MIT as an area of concentration within the undergraduate Humanities, Arts, and Social Sciences Requirement. It is also represented as a graduate field of study in the Whitaker College's Department of Brain and Cognitive Sciences (Course IX). An undergraduate major in cognitive science, briefly described as the psychology of human intellect, is also available. Students who wish to concentrate in psychology may choose from a range of subjects offered by Course IX. These subjects may also be counted as HASS electives.

In addition to taking psychology subjects, undergraduates may take advantage of a wide range of research opportunities existing in the Department of Brain and Cognitive Sciences under the Undergraduate Research Opportunities Program (UROP).

For more information about the Department of Brain and Cognitive Sciences and the undergraduate major, see the description of Course IX under the Whitaker College of Health Sciences, Technology, and Management. For more information about the HASS concentration and electives in psychology, contact Professor Susan Carey, Room E10-039, 253-5768.

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 humanistic 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 1986-87 is Professor Catherine Chvany, Room 14N-221C, 253-6341.

Traditions and Texts

This program provides a series of interdisciplinary humanistic subjects designed to introduce undergraduates to some of the major cultural traditions of civilization as expressed in written texts and works of art. Most of these subjects deal with principal periods in Western tradition, ranging from ancient Greek and Biblical studies through the Middle Ages and Renaissance to the Modern period, but there are also subjects focused on the traditions of East Asia and the Islamic world. Cutting across various forms of thought and expression — religion, philosophy, history, literature, and the arts — the consistent aim of this program is to make intelligible the changing network of values which link a society's present with its past and future, and to trace the processes of transmission and rebuilding which occur within it. The subjects are taught by faculty from several humanistic fields. Traditions and Texts is available as a field of concentration.

Information on Traditions and Texts may be obtained from the Humanities, Arts, and Social Sciences Information Center, Room 14N-409, 253-4441.

Women's Studies Program

Women's Studies involves a re-cognition 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. The program also offers a Humanities concentration in Women's Studies.

The program is described in greater detail in Chapter III. Further information may be obtained from Dr. Ruth Perry or Cynthia Brown, Room 14E-316, 253-8844.

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School Faculty and Staff Without Departmental Affiliation

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Director of Women's Studies

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Beth Soll, B.S.
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William Nash Locke, Ph.D.
Professor of Modern Languages, Emeritus
Director of Libraries, Emeritus

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and Social Science

Oliver D'Arcy Hart, Ph.D.
Professor of Economics

Jerry Allen Hausman, D.Phil.
Professor of Economics
(On leave, fall)

Alberto Holly, Ph.D.
Professor of Economics
(Visiting, fall)

Paul Lewis Joskow, Ph.D.
Professor of Economics

Paul Robin Krugman, Ph.D.
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Associate Professor of Economics
(On leave)

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Assistant Professors

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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 the behavior of economic units, institutions, and systems and the choices that they make with respect to the allocation of scarce resources among production and consumption. The study of economics provides an understanding of important aspects of current society: the determinants of wealth, income, poverty, jobs, and prices; the impact of government policy upon the economic behavior of firms, individuals, and society; the structure of markets and their allocation of resources in the context of equity and efficiency.

Economics is concerned with a wide range of problems that directly affect society: the causes of unemployment and price rigidity; productivity and economic growth; foreign debt and trade linkages; union behavior and the structure of labor markets; taxation and incentives; and the role of government in private markets.

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 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 select programs that emphasize the relation of technology to economics by concentrating their free elective time in science and engineering; they may choose programs that concentrate more heavily on economics and other social sciences; or they may undertake to relate economics to history, philosophy, or literature. The successful completion of the degree prepares students for study in economics, industrial relations, business administration, law, and related fields, or for careers in teaching, government, research, unions, finance, and business.

The aims of the degree program are threefold: to give students a firm grounding in modern economic theory; to provide a basic descriptive knowledge of the US and world economy; and to develop in students the capability for quantitative research and independent thought. These aims roughly correspond to the requirements in the Course XIV curriculum of theory, electives, statistics, and research.

The requirements allow substantial freedom for students in designing individual programs within economics and in 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 who have taken 14.01 Economic Principles I and 14.02 Economic Principles II by the end of their second year can follow a program which permits considerable depth in electives in the third and fourth years. The most satisfactory plan is to take 14.04 Intermediate Microeconomic Theory and 14.06 Intermediate Macroeconomic Theory in successive terms of the third year and to complete 14.31 Econometrics before the end of the third year. This satisfies prerequisites for all subjects and prepares students for thesis research.

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	Economic Principles I, 9	
14.02	Economic Principles II, 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], 12; 14.04, 14.06, 14.31	
	Thesis (9 units)	
Restricted Electives:		45-60
Elective subjects in economics		
Units in Departmental Program that also satisfy the General Institute Requirements		(51-60)
Unrestricted Electives		99-105
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.

Graduate Study

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	Economic Principles I, 9	
14.02	Economic Principles II, 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], 12; 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.

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. A student whose deficiencies are of minor extent may be permitted graduate registration while taking appropriate subjects to remove them.

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, monetary economics, fiscal economics, industrial organization, transportation, international economics, economic development, Russian and Soviet economics, comparative economic systems, urban economics, labor economics, economic history, econometrics, human resources and the distribution of income and wealth, and (given outside the Department) finance. The econometrics requirement may be satisfied by offering it as a field or by taking 14.388 Applied Econometrics and, in either case, completing a major piece of empirical research. The minimal economic history requirement can be satisfied by taking one subject in the field.

No stated number of graduate subjects in the Department is required. However, candidates ordinarily need two full academic years of study to prepare adequately for the General Examination 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 planning problems of the city 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 teaching and research assistantships. Typically, these appointments 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 Peter A. Diamond, E52-373A, MIT, 50 Memorial Drive, Cambridge, Massachusetts 02139, (617) 253-3362.

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 which help to satisfy the Institute Requirement in Humanities, Arts, and Social Sciences, include **Distribution Subjects** and **Fields of Concentration,** and are available as **undergraduate degree programs** 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 the Course XXI Office, Room 14N-407, MIT, Cambridge, Massachusetts 02139, (617) 253-4446.

Anthropology/Archaeology

Arthur Steinberg, Ph.D.
Associate Professor of Archaeology
Program Head

Martin Diskin, 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
(On leave, spring)

James Howe, Ph.D.
Associate Professor of Anthropology

Jean Elizabeth Jackson, Ph.D.
Associate Professor of Anthropology
(On leave)

Sharon Traweek, Ph.D.
Associate Professor of Anthropology
and Science, Technology, and
Society
(On leave)

Harry V. Merrick, Ph.D.
Lecturer in Anthropology

Lynn Stephen
Lecturer in Anthropology

Jonathan Wylie, Ph.D.
Lecturer in Anthropology

Frederick Wiseman, Ph.D.
Lecturer in Archaeology
Principal Research Scientist,
Center for Materials Research in
Archaeology and Ethnology

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 Japan 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 V. Students may participate in research projects by arrangement with the appropriate faculty members.

The Anthropology/Archaeology curriculum is divided into five groups which show the breadth of the field, with particular emphases. Introductory subjects (21.50-21.505) encompass broad topics such as human evolution and archaeological methods. Social Anthropology subjects (21.511-21.532) 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 (21.535-21.542) focus on various early and modern technologies and how they relate to their cultural settings. The Archaeology subjects (21.550-21.563) 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 are open only to graduate students and qualified upperclassmen and have prerequisites; 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."

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-131A, (617) 253-3065.

Foreign Languages and Literatures

Claire J. Kramsch, M.A.
Professor of Foreign Language Acquisition
Section Head

Catherine Vakar Chvany, Ph.D.
Professor of Russian

James Wesley Harris, Ph.D.
Professor of Spanish and Linguistics

Robert Emmet Jones, Ph.D.
Professor of French and Humanities

Krystyna Pomorska, Ph.D.
Professor of Russian and Literature
(On leave)

Isabelle de Courtivron, Ph.D.
Associate Professor of French
(On leave, fall)

Kathryn Crecelius, Ph.D.
Associate Professor of French
(On leave, fall)

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

Joseph Brami, Ph.D.
Assistant Professor of French
(On leave, spring)

Suzanne Flynn, Ph.D.
Assistant Professor of English as a Second Language

Edith Waldstein, Ph.D.
Assistant Professor of German
(On leave, spring)

Robert Di Donato, Ph.D.
Lecturer in German

David Dollenmayer, Ph.D.
Lecturer in German

Kathy Irving, M.A.
Lecturer in English as a Second Language

Gilberte Furstenberg, M.A.
Lecturer in French

Jacqueline Hill, M.Ed.
Lecturer in French

Douglas Morgenstern, M.A.
Lecturer in Spanish

Christopher Sawyer-Laucanno, Ph.D.
Lecturer in English as a Second Language

Elena Semeka-Pankratova, Ph.D.
Lecturer in Russian

Ruth Trometer
Director of the Language Laboratory

Karen Bushold
Administrative Officer

Margaret Zaroodny Freeman, S.M.
Associate Professor of Russian, Emerita

Richard Felix Koch, A.M.
Assistant Professor of Modern Languages, Emeritus

Foreign Languages and Literatures

The Foreign Languages and Literatures Section offers a variety of programs. There are subject sequences in French, German, Greek, Russian, Spanish language and literature taught in the original, a subject sequence on literature taught in English translation; and a comprehensive program in English as a second language.

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.

In the programs at MIT, "introductory subjects" familiarize students with the basic principles of the language in both its spoken and written forms, and introduce the culture of the countries where the language is spoken. The "intermediate level" provides for review and refinement of grammar, study of more difficult reading matter with cultural and literary content, and compositions and discussions in the foreign language. "Advanced subjects" conducted in the foreign language stress analysis of the form and content of the literature and study of the culture and civilization of each country. A well-equipped language laboratory facilitates language learning.

Subjects in literature in translation make available in English great works from foreign literatures. These subjects enable students who do not know the original language to experience new avenues of thought, vision, and feeling. Although these subjects are given in English, students with a reading knowledge of a specific language will be encouraged to read works in the original. Courses in this sequence range from broad introductory subjects to more specific aspects of literary study.

In choosing language subjects, students should bear in mind that credit toward graduation is not given for repeating work offered for admission to MIT. Concentrations in any field of language and/or literature should be arranged on an individual basis in consultation with a designated advisor.

Proficiency in a foreign language is a prerequisite for election to Phi Beta Kappa.

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. There are circumstances under which one or more subjects not conducted in the language may be counted in the degree requirements.

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

Pauline Maier, Ph.D.
Professor of History
Section Head

Richard Mateer Douglas, Ph.D.
Professor of History
(On leave, fall)

Robert Michael Fogelson, Ph.D.
Professor of History and
Urban Studies

Loren Graham, Ph.D.
Professor of the History of
Science

Robert Ellsworth MacMaster, Ph.D.
Professor of History and Literature

Bruce Mazlish, Ph.D.
Professor of History

Harald Anton Thrap Olsen Reiche,
Ph.D.
Professor of Classics and Philosophy

Robert Irwin Rotberg, D.Phil.
Professor of History and Political
Science

Merritt Roe Smith, Ph.D.
Professor of the History of
Technology

Peter Hopkinson Smith, Ph.D.
Professor of History and
Political Science

Arthur Daniel Kaledin, Ph.D.
Associate Professor of History and
American Studies

Philip S. Khoury, 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.
Assistant Professor of History

Michael E. McGerr, Ph.D.
Assistant Professor of History
(On leave, spring)

Peter Cushing Perdue, Ph.D.
Assistant Professor of History

Howard Russell Bartlett, B.S., A.M.
Professor of History, Emeritus

Lynwood Silvester Bryant, A.M.
Professor of History and American Studies,
Emeritus

Edward Neal Hartley, A.M.
Professor of History, Emeritus
Institute Archivist, 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.

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 21.491 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

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
Director, Humanities
Undergraduate Office

Irene Tayler, Ph.D.
Professor of Literature
(On leave, fall)

David Thorburn, Ph.D.
Professor of Literature

Cynthia Griffin Wolff, Ph.D.
Class of 1922 Professor of Literature

Peter Samuel Donaldson, Ph.D.
Associate Professor of Literature

David Martin Halperin, Ph.D.
Associate Professor of Literature

John Hildebidle, Ph.D.
Class of 1922 Career Development
Associate Professor of Literature
(On leave, fall)

Amy Schraeger Lang, Ph.D.
Associate Professor of Literature

Steven Mullaney, Ph.D.
Associate Professor of Literature

William J. Paul, Ph.D.
Associate Professor of Literature

Stephen James Tapscott, Ph.D.
Associate Professor of Literature
(On leave)

Rita Bettina Goldberg, Ph.D.
Assistant Professor of Literature

Theoharis Constantine Theoharis, Ph.D.
Assistant Professor of Literature

Ruth Perry, Ph.D.
Senior Lecturer in Literature and
Women's Studies

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 Humanities 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 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

Marcus Aurelius Thompson, D.M.A.
Professor of Music
Section Head

John LaBoiteaux Buttrick, M.S.
Professor of Music

David Mayer Epstein, Ph.D.
Professor of Music
Conductor of the MIT Symphony Orchestra

Stephen Erdely, Ph.D.
Professor of Music

John Harbison, M.F.A.
Class of 1949 Professor
Professor of Music

Barry Lloyd Vercoe, D.M.A.
Professor of Music

Jeanne Shapiro Bamberger, M.A.
Associate Professor of Music

Jane Coppock, Ph.D.
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

Pamela Wood Ambush, M.M.
Lecturer in Music

Betsy Burleigh, M.M.
Lecturer in Music

Mark Harvey, Ph.D.
Lecturer in Music

Martin Marks, M.A.
Lecturer in Music

Roland Vazquez, M.A.
Lecturer in Music

Claudia Von Canon, M.A.
Lecturer in Music

Nancy Trudeau Cavanagh, B.A.
Administrative Officer

James David Christie, M.M.
Institute Organist

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.

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 and three subjects in history and literature of music. 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. Seniors in the Full Major participate in a tutorial program in preparation for a General Examination; those in the Joint Major take a Senior Music Seminar. Especially qualified students may be permitted to substitute a thesis on an analytical or historical topic or an original composition for the General Examination or 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.
Thomas Meloy Professor of Rhetoric

Bernard Avishai, Ph.D.
Associate Professor of Writing

Rae Goodell, Ph.D.
Associate Professor of Science Writing

James Paradis, Ph.D.
Associate Professor of Technical Communication

Harriet Ritvo, Ph.D.
Associate Professor of Writing

Robin Becker, M.A.
Assistant Professor of Writing

Marcel La Follette, Ph.D.
Assistant Professor of Writing

Marilyn Richardson, B.A.
Assistant Professor of Writing

Rosalind Williams, Ph.D.
Assistant Professor of Writing

Joe Haldeman, M.F.A.
Adjunct Professor of Fiction

Janette Turner Hospital, M.A.
Visiting Writer
(spring)

Fanny Howe
Visiting Writer
(fall)

Ilona Karmel, A.B.
Senior Lecturer in Writing

Maxine Kumin, A.M.
Visiting Writer

Steven Strang, Ph.D.
Lecturer in Writing

Charles Fuller, B.M., B.M.Ed.
Administrative Officer

Janet H. Murray, Ph.D.
Principal Research Scientist

Philip N. Alexander, M.S.
Research Associate

Ann H. Stewart, Ph.D.
Research Affiliate

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.

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 (253-3039).

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 progrms may be obtained from the Writing Program Office, Room 14E-310, (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 which combines 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 STS/Humanities, 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)
STS/Humanities

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 or general examination. 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, only 1 subject being used to meet the Distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the departmental requirement for the full major.
2
The minor program 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	**17 Subjects**
Science Requirement	5
Humanities, Arts, and Social Sciences Requirement [all but two Humanities Distrbution subjects can be satisfied by subjects in the Departmental Program][1]	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, the relevant field office, and the Humanities Undergraduate Office)	
Anthropology/Archaeology 8 subjects in the field (including 21.501, 21.502, and 21.503 or 21.504), a 4-subject minor[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 minor[2], a pre-thesis tutorial, and a thesis	126-162
History 9 elective subjects in the field, a 4-subject minor[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 minor[2]	135-168
Music 10 subjects in the field (including 21.621, 21.622, 21.641, 21.642, and 21.643, and a year of ensemble performance), a 4-subject minor, a pre-exam or pre-thesis tutorial, a general exam or thesis.	153-177
Writing Creative or Expository: 5 subjects centered in creative or expository writing (including 1 advanced subject), four subjects in a related field of humanities, arts, or social science, a 4-subject minor[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 minor[2], a pre-thesis tutorial, and a thesis	141-165
Restricted Electives (continued)	
STS/Humanities (The full major in STS/ Humanities 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 21.901J/STS 130J, 21.902J/STS 131J, and 21.903J/STS 132J, and study in three STS areas), a 4-subject minor[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, general examination, 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
STS/Humanities

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 — STS/Humanities — 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][1]	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, the relevant field office, and the Humanities Undergraduate Office)	
Anthropology/Archaeology 7 subjects (including 21.501, 21.502, and 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, a year of ensemble performance, and a senior seminar or thesis).	81-108
Restricted Electives (continued)	
Writing	
Creative or Expository: 4 subjects centered in creative or expository writing (including 1 advanced subject), 3 subjects in a related field of humanities, arts, or social science, 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), a pre-thesis tutorial, and a thesis	81-102
STS/Humanities 8 subjects (including 21.901J/STS 130J and 21.902J/STS 131J 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 Undergraduate Office)	
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.

2
American Studies, Latin American Studies, and Russian Studies are also available as full majors by special arrangement with the Humanities Undergraduate Office.

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.

Inquiries

Additional information concerning degree programs and other opportunities in Course XXI may be obtained from Professor Travis R. Merritt, Director of the Humanities Undergraduate Office, Room 14N-405, MIT, Cambridge, Massachusetts 02139, (617) 253-4446.

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	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[1] 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, the relevant field office, and the Humanities Undergraduate Office)	
Anthropology/Archaeology 8 subjects in the field (including 21.501, 21.502, and 21.503 or 21.504), a 4-subject minor[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 minor[2], a pre-thesis tutorial, and a thesis	at least 126
Restricted Electives (continued)	
History 9 elective subjects in the field, a 4-subject minor[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 minor[2]	at least 135
Music 10 subjects in the field (including 21.621, 21.622, 21.641, 21.642, and 21.643, and a year of ensemble performance), a 4-subject minor,[2] a pre-exam or pre-thesis tutorial, a general exam or thesis.	at least 153
Writing Creative or Expository 5 subjects centered in creative or expository writing (including 1 advanced subject), four subjects in a related field of humanities, arts, or social science, a 4-subject minor[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 minor[2], a pre-thesis tutorial, and a thesis	at least 141
STS/Humanities (The full major in STS/ Humanities 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 21.901J/STS 130J, 21.902J/STS 131J, and 21.903J/STS 132J, and study in three STS areas), a 4-subject minor[2], a pre-thesis tutorial, and a thesis	at least 126
Unrestricted Electives	99 to 66
Total Units Required for the S.B. Degree	360

1
As a matter of general Course XXI policy, only 1 subject being used to meet the Distribution element of the Humanities, Arts, and Social Sciences Requirement may be counted toward the departmental requirement for the full major.

2
The minor program 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, the relevant field office, and the Humanities Undergraduate Office)

Anthropology/Archaeology 7 subjects (including 21.501, 21.502, and 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

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, a year of ensemble performance, and a senior seminar or thesis).	at least 81
Writing Creative or Expository: 4 subjects centered in creative or expository writing (including 1 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), a pre-thesis tutorial, and a thesis	at least 81
STS/Humanities 8 subjects (including 21.901J/STS 130J and 21.902J/STS 131J 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 Undergraduate Office)	
Unrestricted Electives	85 to 96
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
American Studies, Latin American Studies, and Russian Studies are also available as full majors by special arrangement with the Humanities Undergraduate Office.

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.

Department of Linguistics and Philosophy

(Course 24)

Richard Lee Cartwright, Ph.D.
Professor of Philosophy
Head of the Department

Professors

Ned Block, Ph.D.
Professor of Philosophy

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

Robert C. Cummins, Ph.D.
Professor of Philosophy
(Visiting)

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

Richard Kayne, Ph.D.
Professor of Linguistics

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

Irving Singer, Ph.D.
Professor of Philosophy

Judith Jarvis Thomson, Ph.D.
Professor of Philosophy
(On leave)

Associate Professors

Joshua Cohen, Ph.D.
Associate Professor of Philosophy
and Political Science

James Higginbotham, Ph.D.
Associate Professor of Philosophy
(On leave, spring)

Paul Horwich, Ph.D.
Associate Professor of Philosophy

Luigi Rizzi, D.Lit.
Associate Professor of Linguistics
(On leave, spring)

Assistant Professors

Judith Wagner DeCew, Ph.D.
Assistant Professor of Philosophy

Richard K. Larson, Ph.D.
Assistant Professor of Linguistics

Donca Steriade, Ph.D.
Assistant Professor of Linguistics

Lecturer

Jeremy S. Hyman, M.A.
(Visiting, fall)

Administrative Officer

Marilyn Matthes Silva, A.B.

Undergraduate Study

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.

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.

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**

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.

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4.726J Site Planning

(Same subject as 11.336J)
Prereq.: Permission of Instructor
G (2)
4-4-4

See description under subject 11.336J.
G. Hack

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

4.742J Facility Programming and Management (A)

(Same subject as 11.312J)
Prereq.: —
G (2)
3-0-6

See description under subject 11.312J.
T. F. Lee

4.743J Housing and Neighborhood Planning (A)
(Revised Content and Unit)

(Same subject as 11.420J)
Prereq.: 11.200 or 4.144
G (2) **Not to be offered 1987-88**
4-0-8

See description under subject 11.420J.
P. Clay

4.745J Environmental Programming Workshop (A)
(Revised Unit)

(Same subject as 11.311J)
Prereq.: Permission of Instructor
G (2)
3-0-6

The methods of determining and specifying needs for change in the built environment. Includes utilization of social science information and feedback from existing projects, formulation of issues with respect to proposed environments, development of consensus on degree of change and design approach. Case studies of programming efforts at the building and city scales for various public, institutional, and residential environments, and "hands-on" exercises in conjunction with private and public decision-making agencies.
S. C. Howell

4.746J Implementation Strategies for Urban Design

(Same subject as 11.337J)
Prereq.: Permission of Instructor
G (1)
Arr.

See description under subject 11.337J.
J. de Monchaux, D. Frenchman

4.747J Theory of City Form (A)
(Revised Unit)

(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 city making, social structure, and physical design.
J. Beinart

4.748J Cities of Tomorrow (A)

(Same subject as 11.335J)
Prereq.: Permission of Instructor
G (1)
3-0-6

See description under subject 11.335J.
D. Frenchman

4.751 Urbanization in Developing Countries: People, Dwellings, Land (A)

Prereq.: Permission of Instructor
G (1)
3-3-6

Identifies changing dwellings/land situations in relation to cultural, social, economic, and physical factors. Provision of land and services for the most needy sectors of the population. Actual practice in Africa and Latin America forms the frame of reference as well as its main sources. Extensive use of case studies of actual projects.
R. Goethert

4.753J Local Housing Policies in Developing Countries
(New)

(Same subject as 11.463J)
Prereq.:—
G (2)
3-0-6

See description under subject 11.463J.
B. Sanyal, R. Goethert

4.764 Culture, Place, and Architecture (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Introduces issues about culture, place, and architecture. Discusses appropriateness of various definitions of culture in explaining and describing the built environment and looks at cultural sources for the design of place and buildings in several different societies — traditional and contemporary. Research about culture to effect a richer understanding of architectural meaning and form.
E. Robbins

4.766J Community, Class, and Race: A Social Perspective (A)

(Same subject as 11.328J)
Prereq.: Permission of Instructor
G (2)
3-0-6

The nature of the community as a social reality. Emphasizes the different meanings of the concept "community." Discusses the methodological assumptions and problems underlying notions of community. Cases cover the theory of community; the community study in America and Europe; community as place; class, race, ethnicity, and community. Readings and evaluations of theoretical, descriptive, and methodological writings on community.
E. Robbins

4.767J Planning in Socialist Countries (A)

(Same subject as 11.417J)
Prereq.: Permission of Instructor
G (1)
3-0-6

See description under subject 11.417J.
T. Lee

4.771 Behavior in the Built Environment

Prereq.: Permission of Instructor
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

4.801 Art and the Environment

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 chances effected by current science and technology vis-à-vis our place in nature and history.
O. Piene

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 non-verbal 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

4.826 Form and Color Workshop

Prereq.: *4.825*
U (1, 2) HASS
0-6-3

Sequence of study projects involving color and area, texture, periodic patterns, random configurations, color depth, black and white, visual vibrations, color and natural form, volume, structure, motion, object and the color environment, and the visual influence of color on spaces.
R. Filipowski

4.827 Plastic Composition

Prereq.: 4.824
U (2) HASS
2-4-6

Continuity of surfaces, synthesis of diverse geometries, group form relationships, object and the landscape, and the optimum three-dimensional relationship of the object form basis for studying plastic sculptural composition. Emphasizes inventiveness and meaning of sculptural 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 Environmental Art

Prereq.: —
U (1) 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)
0-8-12

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)
0-3-2

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)
0-3-2

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)
0-3-2

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

4.870 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 photographic, print, typographic, electrostatic, video, electronic, and other graphics/imaging tools in two and three dimensions. Group exploration of mass-media tools from printing to video and audio as a final public presentation. Lab fee.
M. Cooper

4.871 Graphics Communication Workshop

Prereq.: —
U (2) HASS
2-4-6

Thinking and communicating visually and sensorially by design. Applies static and dynamic graphic principles to the design of 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 media presentation of issues and ideas in such forms as photo essays, printed reports, slide shows, videotapes. Lab fee.
M. Cooper

4.872 Graphics/Imaging Workshop: Print Media

Prereq.: 4.870 or 4.871
G (1)
2-4-6

Comprehensive, production-based workshop in graphic systems from photography to typography to lithography addressing the relationship between tools and the messages they convey. Emphasizes synthesis of verbal and visual communication skills and development of work from concept to product. Graphic arts darkroom experience leads to individual and group projects in variety of print media from photographic techniques and offset printing to electronic scanning and digital typesetting. Open to qualified undergraduates.
M. Cooper

4.873 Graphics/Imaging Workshop: Transmission Media

Prereq.: 4.870 or 4.871
G (2)
2-4-6

Explores image processing systems and transformations allowing their output in two-, three-, or four-dimensions through any of the senses. Centers on analog and digital forms of expression that can be transmitted locally and globally through such means as personal and public networks, telephone, cable, and satellite in order to gain a heightened understanding of communication systems and their physical and ideational transforms. Explores notions of "image" beyond those traditionally accepted. Open to qualified undergraduates.
M. Cooper, R. MacNeil

4.874 Graphics/Imaging Workshop: Color

Prereq.: 4.870 or 4.871
G (1)
2-4-6

Explores the uses of color theories such as modern additive and subtractive synthesis. Creates graphic color expressions in analog and digital imaging systems at the Visible Language Workshop and transforms them through color image enhancement, manipulation, and conversion from one medium to another. Uses both the VLW electronic scanner and computer graphic/imaging system to allow realization in traditional photomechanical print systems such as color coupler materials, offset lithography, and dye transfer. Open to qualified undergraduates.
R. MacNeil

4.875 Computer Graphics Workshop I

Prereq.: 4.870 or 4.871
G (1)
2-4-6

4.876 Computer Graphics Workshop II

Prereq.: 4.876
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 which can be installed as part of that system. Open to qualified undergraduates.
R. MacNeil

4.878, 4.879 Graphics/Imaging Media Projects

Prereq.: 4.870 4.871
U (1, 2)
Arr.

Special work on an individual or group basis combining research and projects in graphics/imaging media. Registration subject to prior arrangement for project and supervision by staff.
M. Cooper

4.880 Media Communication Seminar and Workshop (A)

Prereq.: Permission of Instructor
G (1)
2-4-6

Explores synthesized production of media art and technology in a three-part format of research, projects, and presentations: 1) the production and evaluation of personal projects; 2) presentations by participants and researchers in art and technology; 3) seminars on media art and technology theory and issues. Topics: computer typography, animation, and imaging systems work culminates in a short conference, exhibition, and documentation of projects.
M. Cooper, R. MacNeil

4.881 Graphics/Imaging Media Research Methods (A)

Prereq.: 4.880
G (2)
2-4-6

Investigates the intrinsic similarities and differences between research modes and issues in the arts, humanities, science and technology. Develops new models of research communication. Selected speakers and presentations. Final project includes the documentation, presentation, and defense of a pre-thesis project.
M. Cooper, R. MacNeil

4.887–4.889 Graphic Imaging Media Projects (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Special work on individual or group basis combining research and projects in graphics/imaging media. Registration subject to prior arrangement for subject matter and supervision by staff.
M. Cooper

4.901 Creative Seeing

Prereq.: —
U (1) HUM-D
3-0-6

Creative Seeing offered by photographers, filmmakers, visual designers, and art critics. While each has a unique way of presenting and visually manipulating the world, all are involved in Creative Seeing. Their common aim is to allow students to experience this level of vision by personal subjective discovery. Organized into parts each conducted within one of the fields. Limited enrollment. Preference to freshmen and sophomores.
M. Cooper

4.905 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

4.908 Special Projects in Visual Arts

Prereq.: Permission of Instructor
U (1, 2)
Arr.

4.909 Special Projects in Visual Arts (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Supplementary work on individual and group basis on visual arts projects involving more than one medium. Registration subject to prior arrangement of subject matter and supervision by staff.
Staff

4.915 Basic Photography for Architects

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 between 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

4.921 Creative Photography I

Prereq.: —
U (1, 2) HASS
4-4-4

Introductory subject covering both large and small format cameras, exposure and development of film, printing, and final presentation. Varied assignments encourage exploration of all aspects of creative photography. Assumes that possibilities for personal expression increase as technique grows. Lab fee.
M. Cooper

4.924 Creative Photography II

Prereq.: 4.921
U (2) HASS
3-0-9

Intermediate level production subject emphasizing the student's unique vision. Requires a substantial project. Weekly critiques, readings, and intensive study of related well-known photographic work. Lab fee.
M. Cooper

4.927 Advanced Photography (A)

Prereq.: Permission of Instructor
G (1)
2-5-5

Production-oriented workshop in photography. Students pursue and develop own unique styles. Explores advanced technical problems and various methods of evaluating images.
M. Cooper

4.928 Special Projects in Photography

Prereq.: 4.921
U (1, 2)
Arr.

Photographic production projects on an individual basis. Work in various fields of photography not covered by regular subjects. Registration subject to prior arrangements of subject matter and supervision.
M. Cooper

4.929 Special Advanced Projects in Photography (A)

Prereq.: 4.921
G (1, 2)
Arr.

Advanced photographic production projects on an individual or group basis. Work in various fields of photography not covered by regular subjects. Registration subject to prior arrangements of subject matter and supervision.
M. Cooper

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

4.946J Cognitive Aspects of Musical Development and Learning (A)

(Same subject as 21.668J)
Prereq.: Permission of Instructor
G (1)
3-6-3

See description under subject 21.668J.
J. S. Bamberger, S. A. Papert

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 for subject matter and supervision by staff.
S. A. Papert

4.953 Spatial Imaging Systems

Prereq.: Permission of Instructor
G (1)
3-3-3

Surveys the technology of spatial imaging from stereoscopes to holograms, emphasizing unaided viewing systems, and explores the perceptual, technical, and aesthetic bases of satisfying three-dimensional image communication. Includes a review of the elements of imaging optics. Lab fee. Open to qualified undergraduates.
S. Benton

4.954 Holographic Imaging

Prereq.: Permission of Instructor
G (2)
3-3-3

A laboratory-based exploration of the principles, techniques, and applications of holography as a visual medium, emphasizing white-light holograms and digital/photo/optical syntheses of quasiholographic images. Lab fee. Enrollment limited. Open to qualified undergraduates.
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)
(New)

Prereq.: —
G (1, 2, S)
Arr.

For research assistants in Media Technology in cases where the assigned research is approved for academic credit by the Department.
N. Negroponte

4.966-4.969 Special Topics in Media Technology (A)
(New)

(4.259)
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
(Revised Content)

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

4.977 Special Projects in Television Production
(Revised Content)

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)
(Revised Unit)

Prereq.: Permission of Instructor
G (1)
Arr.

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)
(Revised Content)

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

4.983 Visiting Artists Workshop (A)

Prereq.: 4.981
G (2)
Arr.

Advanced seminar sharing theoretical and technical problems of moviemaking approach, structure and subject development, and editing with visiting film/video makers, technical experts, fellow students, faculty, and staff. May include special workshops in group production or technical subjects. Final paper. Required of all graduate students in Film/Video section.
R. Leacock

4.984 Design Project in Film/Video Technology (A)

Prereq.: Permission of Instructor
G (1)
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

4.985 Film/Video and Its Technology (A)

Prereq.: 4.981
G (2)
4-4-4

A direct approach to technical concerns of the independent filmmaker for all phases of film/video production including sound, super-8 and 16-mm film, video. Topics: lens and camera options, raw stocks, printing techniques; microphones and recording techniques, audio processing and mixing; lighting; basic electricity, electronics, and power systems; video cameras, recorders, and editing systems and options; film video transfers; field maintenance.
R. Leacock

4.986 Special Projects in New Media (A) (New)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Group projects in media/performance, educational video disc and/or other applications requiring the use of computational video. Target problems and a range of approaches analyzed as production is designed and implemented.
Staff

4.988 Workshop in Elastic Movie Time (A)

Prereq.: 4.982, 4.985
G (1, 2)
6-8-2

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.
B. Bergery

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

4.991 Introduction to the History of Film

Prereq.: —
U (1) 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 technology to film form and content. Some elementary moviemaking exercises. Requires final paper. Lab fee.
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

5.UR Undergraduate Research

Prereq.: —
U (1, 2)
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.: 5.41 or 5.11
U (2)
4-0-8

Presents theoretical principles of chemical bonding and molecular structure, and their application to the chemistry of all the elements of the periodic system.
D. Seyferth, M. S. Wrighton

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 (1)
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, bioinorganic chemistry, and reactivity patterns of the heavier elements.
S. J. Lippard, R. R. Schrock

5.065 Advanced Inorganic Chemistry (A)

Prereq.: 5.03
G (2)
3-0-6

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

5.066 Introductory Bioinorganic Chemistry (Revised Unit)

Prereq.: 5.03
G (2) **Next offered 1987-88**
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 principle methods useful in metallobiochemistry. Considers the principal types of metalloproteins.
W. H. Orme-Johnson, S. J. Lippard

5.067 Inorganic Chemistry (A)

Prereq.: 5.03
G (1)
2-0-4

Transition metal catalysis. Consists of 1) a discussion of principles of catalysis, evolution of catalytic systems and experimental techniques; 2) a survey of reaction types and metal catalysts; and 3) detailed exploration of several exemplary catalytic reactions from a mechanistic viewpoint.
S. J. Lippard

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 and catalysis.
Term 1: *D. S. Kemp, M.S. Wrighton*
Term 2: *A. Davison, G. A. Petsko*

5.12 Organic Chemistry I

Prereq.: 5.11
U (2) SD
5-0-7

Introduction to organic chemistry. Emphasis on organic functional groups and their interrelations. Substitution and elimination chemistry and mechanisms covered thoroughly. Chemistry of the carbonyl grouping included. Introduction to spectroscopic techniques for structure proof given.
G. A. Berchtold, F. D. Greene

5.13 Organic Chemistry II

Prereq.: 5.11, 5.12
U (1)
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.
J. L. Kinsey, R. A. Alberty

5.311 Introductory Chemical Experimentation

Prereq.: 5.12 or 5.11
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 80 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 polarographic analysis, 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 on the fundamentals of quantum chemistry illustrated through molecular spectroscopy. Projects include NMR, ESR, and computer-interfaced IR spectroscopy; electrode kinetics; synthesis of organometallics under inert atmosphere; and synthesis of polymers.
K. A. Nelson

5.43 Organic Chemistry

Prereq.: 5.13, *5.03*
U (2)
4-0-8

Studies reaction mechanisms emphasizing reactive intermediates, structure-reactivity relationships, and reactions of synthetic value.
S. L. Buchwald, W. Mungall

5.47 Organometallic Chemistry (A)

Prereq.: 5.03, 5.43
G (2) **Next offered 1987-88**
2-0-4

Discusses fundamental processes in organometallic chemistry: Mechanistic aspects, uses in industry and in organic synthesis.
S. L. Buchwald, K. B. Sharpless

5.50J Advanced Biochemistry (A)

(Same subject as 7.75J)
Prereq.: 7.05
G (2)
4-0-8

See description under subject 7.75J.
G. M. Brown, C. T. Walsh

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.
W. R. Roush

5.512 Synthetic Organic Chemistry II (A)

Prereq.: 5.511
G (2)
3-0-6

General methods and strategies for the synthesis of complex carbocyclic and heterocyclic organic compounds.
R. L. Danheiser

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.
S. L. Buchwald, F. D. Greene

5.54 Physical Organic Chemistry (A)

Prereq.: 5.53
G (2)
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.
S. Masamune, K. B. Sharpless

5.57 Chemistry of Amino Acids, Peptides, and Proteins (A)

Prereq.: 5.13
G (2) **Next offered 1987-88**
3-0-6

Synthesis of amino acids and peptides. Protective groups, amideformation, 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.
D. S. Kemp

5.59 Enzyme Physical Chemistry

Prereq.: 5.62
G (2)
2-0-4

Biophysical approaches to mechanisms of enzyme-catalyzed reactions. Analyzes **kinetic** mechanisms from fit of algebraic models to steady-state and pre-steady-state rate data. Interprets structural and spectroscopic data to yield **chemical** mechanisms. Evaluates evidence on sources of rate enhancement. Thermodynamic profiles and evolution of enzyme mechanisms. Emphasizes use of physical methods, particularly with metalloenzymes. Examples mainly from major cellular oxidoreductive processes.
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: *I. Oppenheim, J. S. Waugh*
Term 2: *K. A. Nelson, R. J. Silbey*

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. W. Field

5.62 Physical Chemistry

Prereq.: 5.60 or 10.13
U (2)
4-0-8

Elementary kinetic theory and statistical mechanics; transport properties of gases and liquids; rates of chemical reactions.
C. W. Garland, 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, R. T. Sauer, P. R. Schimmel

5.65J Statistics of Macromolecular Systems (New)

(Same subject as 10.682J)
Prereq.: Permission of Instructor
G (1)
3-0-6

See description under subject 10.682J.
J. M. Deutch, U. M. Suter

5.68 Kinetics of Chemical Reactions (A)

Prereq.: 5.62
G (2) **Next offered 1987-88**
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.
P. W. Phillips

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. Advanced topics in thermodynamics, including irreversible processes.
P. W. Phillips

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.
R. J. Silbey

5.74 Introductory Quantum Mechanics II (A)

Prereq.: 5.73, 18.075
G (2)
3-0-6

Continuation of 5.73 Permutation symmetry and angular momentum. Molecular dynamics. Time-dependent problems, radiation and matter. Scattering by a central field. Many-electron systems, approximate molecular and atomic wave functions.
J. S. Waugh

5.76 Molecular Spectra and Molecular Structure (A)

Prereq.: 5.61 or 5.73 or 8.05
G (2)
3-0-6

Atomic Spectra. Rotational, vibrational, and electronic spectra of diatomic and polyatomic molecules. Assignment of spectra. Structural parameters, molecular models, and effective Hamiltonian matrices. Breakdown of the Born-Oppenheimer approximation. Group Theory, selection rules, normal coordinates. Laser spectroscopy.
R. W. Field

5.80 Special Topics in Chemical Physics (A)

Prereq.: 5.70, 5.73
G (1, 2)
Arr.

Advanced topics of special or current interest. The specific areas announced in advance of each term. Information: R. J. Silbey.

5.82 Advanced Topics in Solid-State Chemistry (A)

Prereq.: 5.70, 5.73
G (1 or 2)
Arr.

Selected topics from areas such as: structure of crystals, surface structure, symmetry groups, diffraction methods, lattice dynamics, order-disorder and magnetic phenomena, molecular motions in solids, relaxation phenomena, optical properties and exciton theory. Information: J. S. Waugh.

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.
M. S. Wrighton

5.90 Special Problems in Chemistry (A)

Prereq.: —
G (1, 2)
Arr.

Directed research and study of special chemical problems. For graduate students only.
G. A. Berchtold

5.912 Seminar in Chemistry for Undergraduates

Prereq.: Permission of Instructor
U (1, 2)
1-0-2

Seminar program for chemistry majors. Research seminars led by faculty in Chemistry. Open to juniors and seniors majoring in chemistry. May be repeated for credit, not to exceed 12 units.
C. T. Walsh, M. S. Wrighton

5.913 Seminar in Organic Chemistry (A)

Prereq.: —
G (1)
1-0-2

5.914 Seminar in Organic Chemistry (A)

Prereq.: —
G (2)
1-0-2

Discusses current journal publications in organic chemistry by graduate students and staff members. Consult G. A. Berchtold.

5.915 Seminar in Analytical Chemistry (A)

Prereq.: —
G (1)
1-0-2

5.916 Seminar in Analytical Chemistry (A)

Prereq.: —
G (2)
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)
1-0-2

5.932 Seminar in Physical Chemistry (A)

Prereq.: —
G (2)
1-0-2

Discusses topics of current interest in physical chemistry by staff members and students.
Term 1: *C. W. Garland*
Term 2: *R. W. Field*

5.941 Seminar in Inorganic Chemistry (A)

Prereq.: —
G (1)
1-0-2

5.942 Seminar in Inorganic Chemistry (A)

Prereq.: —
G (2)
1-0-2

Discusses current research in inorganic chemistry by graduate students and staff.
Term 1: *D. Seyferth*
Term 2: *R. R. Schrock*

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)Metalinguistic 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.
S. D. Senturia, C. L. Searle, J. K. Roberge

6.003 Signals and Systems

Prereq.: 6.001, 6.002
U (1, 2)
4-2-9

Unilateral 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, R. S. Kennedy

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. Multi-level 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 and 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 which employ these devices, with examples chosen from switching circuits, single-ended and differential amplifiers, and integrated-circuit amplifiers.
C. G. Fonstad, Jr., D. J. Epstein

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. Magnetoquasistatic 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.
D. Adler

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, B. B. Mikić, 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., C. J. Terman

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 substantial 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

6.041 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
(New)

(Same subject as 18.423J)
Prereq.: 18.063 or 18.310
U (2)
3-0-9

Introduction to logic and computability theory underlying programming. Functional languages, lambda-calculi, and equational reasoning. Compilation and interpretation among languages and machines. Basic undecidable problems. Rewrite systems: Church-Rosser and termination. Program schemes and first-order formulas. Recursion versus iteration. Elementary logic: completeness of Gentzen's system, Herbrand's theorem, Henkin completeness for type theory, incompleteness. Relation to theorem-proving and logic-programming. Program correctness.
A. R. Meyer

6.045J Automata, Computability, and Complexity
(Revised Unit)

(Same subject as 18.400J)
Prereq.: 18.063 or 18.310
U (1, 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. Introduces mathematical logic.
A. R. Meyer

6.046J Introduction to Algorithms
(Revised Unit)

(Same subject as 18.410J)
Prereq.: 6.001, 18.063 or 18.310
U (1)
4-0-8

Techniques for the design and analysis of efficient algorithms emphasizing methods useful in practice. Broader coverage and less mathematical than 6.851J/18.414J. Topics: Sorting. Data structures for sets: lists, trees, hashing. Graph algorithms: shortest paths, depth-first search, matching, traveling salesman. NP-complete problems. Integer arithmetic: GCD's, primality testing. Fast Fourier transform. Multiplication of polynomials. Dynamic programming. Linear programming. Parallel algorithms.
C. E. Leiserson

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)
3-0-9

See description under subject 18.421J.
S. Goldwasser, H. Rogers, Jr.

6.048J Graph Algorithms

(Same subject as 18.431J)
Prereq.: 18.063 or 18.310 or 18.314
U (1) **Not to be offered 1987-88**
3-0-9

See description under subject 18.431J.
B. Awerbuch

6.061 Modeling and Analysis of Electromechanical Devices

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 Telecommunications Systems

Prereq.: 6.003; *6.041* or *18.313* or *18.440*
U (2)
3-0-9

Introduces basic principles and technology utilized in telecommunication systems. Description of signals and noise in the frequency domain. Analog and digital methods of modulation, demodulation, multiplexing and transmission. Statistical measures of system performance including characterization of data sources, information content, channel capacity and error probability. Application of results to selected communication systems and networks. Outside speakers are invited to participate.
R. S. Kennedy, J. P. Ruina

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.
L. A. Gould

6.101 Introductory 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

Initial lecture format treats combinational logic, flip flops, counters, timing circuits, synchronization techniques, finite-state machines, and the design of more complicated digital systems using microprogramming techniques. This material, accompanied by problem sets and lab exercises, prepares students for the conception, design, and implementation of a complicated digital systems project of their choice: e.g., games, music, microcomputers, digital filters, bit-mapped displays, graphics. Enrollment limited to 250.
D. E. Troxel, T. F. Knight, Jr.

6.114 Real-Time Computing and Control Laboratory

Prereq.: 6.001, 6.032 or 6.004
U (1, 2)
3-7-2

Effective use of mini- and micro-computer systems in laboratory and on-line applications. Software development using a combination of high-level and assemby language to achieve performance consistent with real-time needs. Input-output programming, interrupt systems, direct memory access (DMA), high-speed data acquisition, multi-tasking. Laboratory exercises involve open and closed loop control of physical devices, interactive graphics, and data acquisition.
F. F. Lee, B. R. Musicus

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 interrupts and timing, digital signal processing, microcontroller networks. Major project: the design, construction, programming, and testing of a system using microprocessors as processing elements. Limited enrollment.
R. D. Thornton

6.121J Bioelectronic Project Laboratory (New)

(Same subject as HST 575J)
Prereq.: 6.002 or 6.071
U (2)
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 and oral presentation after completion of project.
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, 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, L. A. Gould, R. D. Thornton

6.151 Semiconductor Devices Project Laboratory

Prereq.: 6.701J or 6.150J
U (1, 2) LAB
0-12-0

Student use of facilities of the Microelectronics Laboratory 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.
R. T. Howe, D. J. Edell, L. R. Reif, C. G. Sodini

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 facilities of the Image Processing Laboratory of the Cognitive Information Processing Group in RLE 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; optical, mechanical, or electronic development of scanners; image processing software development; development of apparatus for study or demonstration in visual psychophysics.
W. F. Schreiber

6.163 Strobe Project Laboratory

Prereq.: —
U (1, 2) LAB
2-8-2

A project laboratory for experiments, involved mainly with the characteristics of electronic flash sources of light and their applications to photography and to measurement problems. A program of experimentation concerned with electronic flash, organized with each group of students at the start of the term. Permission of instructor required.
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 1987-88**
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, etc. Oral presentation and written report. Knowledge of probability helpful. Alternate years.
L. D. Braida, N. I. Durlach

Advanced Undergraduate Subjects and Graduate Subjects by Area

Systems Science and Control Engineering

6.201 Introduction to Dynamic Systems

Prereq.: 6.003
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, 13.47J, 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, B. K. Walker

6.234J Multivariable Control Systems II (A)

(Same subject as 2.155J, 10.29J, 13.48J, 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) (New)

Prereq.: 6.201 or 6.233J
G (2) **Next offered 1987-88**
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 Theory of Linear Systems (A)

Prereq.: 18.06, 6.241 or 6.230 or 6.201 or 6.233J
G (2)
3-0-9

Introduces concepts and methods underlying current research. State space and frequency domain approaches to structure, behavior, control of linear systems. Canonical forms, standard forms and numerical computations. Realization theory; Grammians, balanced realizations, model reduction. Geometric theory—controlled, conditionally and almost invariant subspaces. Polynomial matrix descriptions, system equivalence; transfer matrices, multivariable poles and zeros; coprime factorizations. Compensator parametrization; H^∞ optimization.
S. K. Mitter, G. C. Verghese, B. C. Levy

6.243 Theory of Nonlinear Systems (A)

Prereq.: 18.100, 18.06, 6.241 or 6.230 or 6.201 or 6.233J
G (1) **Not to be offered 1987-88**
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. Stochastic dynamical systems and stochastic stability. Alternate years.
S. K. Mitter

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, J. B. Orlin

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

6.262 Markov Models and Their Applications (A)

Prereq.: 1.07 or 6.041 or 6.431 or 18.313
G (1)
3-0-9

Formulation and analysis of dynamic probabilistic models, emphasizing Markov processes and their extensions. Linear systems theory applied to discrete state, discrete and continuous time, stationary and nonstationary, Markov and semi-Markov processes. Dynamic programming and its application to the control of Markov systems. Partially observable Markov processes. Applications in societal and engineering systems: population growth, social mobility, systems reliability and maintenance, and congestion processes in communication networks.
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

6.264 Queueing Theory with Applications (A)

Prereq.: 6.262 or 6.432 or 15.973J or 18.445J
G (2) **Next offered 1987-88**
3-0-9

Introduces analysis of queueing systems, with applications in communications, computers, manufacturing, transportation and urban systems. Material presented varies, depending partly on student interests. Typical topics: simple Markovian queues, networks of queues, general (non-Markovian) single and multiple server queues, priority queues, bounds and approximations. Current research opportunities discussed. Alternate years.
P. A. Humblet, R. C. Larson

6.271 Introduction to Operations Research

Prereq.: Permission of Instructor
G (1)
3-0-9

6.272 Introduction to Operations Research

Prereq.: 6.271
G (2)
3-0-9

A two-term introduction to important techniques and problem formulations of operations research. Homework exercises with user-friendly, on-line computer programs. Emphasizes overall approach rather than mathematical theory. Topics: linear programming models and methods, network analysis, optimal sequential decision making, decision analysis, Markov models, queueing models, inventory theory, and simulation. Case studies developed on the computer.
R. C. Larson

6.281J Logistical and Transportation Planning Methods (A)

(Same subject as 1.203J, 11.526J, 13.665J, 15.078J, 16.76J, TPP 43J)
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 of multistage transistor circuits using a computer. Trans-linear circuits. The charge-control model. Introduction to operational-amplifier design and application. Some previous laboratory experience assumed.
J. K. Roberge

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 1987-88**
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) **Next offered 1987-88**
3-0-9

Theory and practice of electronic transduction, circuits, and systems in modern instrumentation, with critical review of alternative implementations and engineering compromise. Emphasizes analog and pulse-signal processing as opposed to purely digital techniques. Topics: representations of signals, noise, and linear systems, time-varying linear systems, nonlinear waveform processing. Discusses feedback, pulse and timing circuits, digital-analog interfaces and microprocessor-controlled signal processors.
S. K. Burns

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: network representations and transformations; relations between time, frequency, and circuit domains; computer simulation; basic limitations and optimal design. Examples: amplifiers; oscillators; switching circuits; VLSI; feedback; circuit analogs for 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, motor drives, and battery electronics. Assumes background in elementary device physics.
J. G. Kassakian

6.335 Fundamental Theory of Nonlinear Networks (A)

Prereq.: 6.003, 6.201 or 6.230 or 6.241 or 6.333 or 18.06
G (2) **Next offered 1987-88**
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: modified nodal analysis, state equations, Lyapunov stability, Brayton-Moser theory. Current topics and applications. Alternate years.
J. L. Wyatt, Jr.

6.336 Simulation of Large-Scale Circuits (A)

Prereq.: 6.003, 6.201 or 6.230 or 6.241 or 6.333 or 18.06
G (1) **Not to be offered 1987-88**
3-0-9

Formulation of network equations via nodal, modified nodal, and tableau analysis. Iterative methods for nonlinear algebraic equations. Numerical solutions of differential equations via forward Euler, backward Euler, trapezoidal, predictor-corrector, and Gear algorithms. Practical speed-up methods for circuit simulation: macromodeling, exploiting sparsity, and latency. Waveform relaxation. Approximate models and methods for timing analysis of digital VLSI circuits. Alternate years.
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 1987-88**
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 Multidimensional Signal Processing (A)

Prereq.: 6.341
G (2) **Next offered 1987-88**
3-0-9

Representation, analysis, and design of multidimensional signals and systems. Multidimensional Fourier transform, z-transform, discrete Fourier transform, and fast Fourier transform algorithms. Multidimensional filter design and implementation. One-dimensional and multidimensional spectral estimation. Array processing. Image enhancement and restoration. Image coding. Alternate years.
J. S. Lim

6.346 Architectures for Digital Signal Processing (A)
(New)

Prereq.: 6.341, 6.823
G (1)
3-0-9

Interrelationships between algorithm design and special purpose computer architectures for digital signal processing. High performance computers. Linear algebra algorithms and machines. Filter, Convolution and Fast Transform architectures. Compilation of algorithms into architectures. Image processing and local neighborhood operators. Transactions oriented signal processing. Term paper or project required.
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

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 or 6.721
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.
L. A. Glasser

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 and Applications (A)

Prereq.: 6.003, 6.041 or 6.431 or 18.313
G (1, 2)
4-0-8

Basic graduate subject in stochastic processes and applications. Intended primarily for students interested in communication, control, or operations research, but also an appropriate foundation for study of stochastic phenomena in signal processing and biomedical engineering. Applications covered include: hypothesis testing, parameter estimation, discrete-time Kalman filter, stochastic processes in linear systems, and queueing processes. Stochastic process theory is developed in sufficient depth to permit thorough treatment of these applications.
J. H. Shapiro

6.435 System Identification (A)

Prereq.: 6.003, 6.041 or 6.431 or 18.313
G (1) **Next offered 1987-88**
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.
F. C. Schweppe

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

6.451 Principles of Communication (A)

Prereq.: 6.003, 6.041 or 18.313
G (1)
3-0-9

Fundamental principles underlying the transmission of digital data over noisy channels. Mathematical description of signals and noise. Digital modulation and signal design. Decision regions and optimum receivers. Intersymbol interference. Introduction to channel capacity and error-free communication over noisy channels. Elements of block and convolutional coding. Topics of current interest.
P. A. Humblet

6.452 Stochastic Filtering and Detection (A)

Prereq.: 6.201 or 6.233J or 6.241, 6.432
G (2)
3-0-9

A unified approach to the areas of filtering, detection, and system identification. Detection of known and stochastic signals in Gaussian and Poisson noise. Linear filtering, Wiener and Kalman filters, parameter identification. Nonlinear filtering for signals in Gaussian noise and point process observations. Applications to areas such as control, communications, radar, sonar, optical communications, and computer networks.
A. B. Baggeroer, S. K. Mitter

6.453 Optical Detection and Communication (A)

Prereq.: 6.041, 6.014
G (2) **Next offered 1987-88**
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 1987-88**
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 1986-87: Squeezed states of light. 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 1987-88**
3-0-9

See description under subject 13.741J.
A. B. Baggeroer, P. N. Mikhalevsky, (Woods Hole Staff): R. C. Spindel

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) **Next offered 1987-88**
3-1-8

See description under subject 12.534J.
A. B. Baggeroer, G. L. Duckworth

Bioelectrical Engineering

6.501 Sound, Speech, Hearing

Prereq.: 6.003
U (1) **Next offered 1987-88**
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. Alternate years.
K. N. Stevens, L. D. Braida

6.523J Computers and Patient Care

(Same subject as HST 550J)
Prereq.: —
G (2)
2-0-4

See description under subject HST 550J.
G. O. Barnett

6.524J General Physiology

(Same subject as 7.51J)
Prereq.: —
U (2) SD
3-0-9

See description under subject 7.51J.
J. Y. Lettvin

6.532J Sensory-Neural Systems (A)

(Same subject as 16.352J)
Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
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 and invertebrate species including mechanical, visual, and other modalities. Alternate years.
L. S. Frishkopf, C. M. Oman

6.541J Speech Communication (A)

(Same subject as 24.968J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
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) **Not to be offered 1987-88**
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 1987-88**
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 1987-88**
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, H. S. Colburn

6.555J Biomedical Signal Processing (A) (New)

(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, R. V. Kenyon

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 media. Case studies: membrane transport; electrode interfaces; electrical, mechanical, and chemical transduction in tissues; electrophoretic, electro-osmotic flows; diffusion/reaction; ECG. Electromechanical interactions in biomaterials and cells; examples from orthopaedic research.
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 1987-88**
4-1-7

See description under subject 2.76J.
F. R. Morgenthaler, P. P. Lele

6.566J Biomedical Measurements (A) (New)

(Same subject as HST 585J)
Prereq.: Permission of instructor
G (1)
3-3-6

See description under subject HST 585J
D. J. Edell, J. C. Weaver, R. S. Newbower

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 Introduction to Optical Electronics

Prereq.: 6.013, 6.003
U (2)
3-0-9

Introduces Fourier optics. Spatial and temporal coherence of lasers and applications made possible by coherence. Characteristics of optical system components: propagation media, resonators, fiber guides; detectors and their signal-to-noise ratios; laser media, types and properties; modulation techniques. Discusses specific applications.
J. H. Shapiro

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 electro-optic 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, 18.075 or 18.04
G (2) **Not to be offered 1987-88**
3-0-9

Intended for first-year graduate students and seniors whose interest is in the interaction of electromagnetic fields with charged particles, plasmas, and continuous media. Wave propagation in media with temporal and spatial dispersion. General stability criteria and techniques for identifying and classifying wave-type instabilities. Energy, momentum, and their flow associated with small-amplitude wave propagation in passive and active media. Linear and nonlinear coupling of modes in stable and unstable systems. Alternate years.
A. Bers

6.634 Nonlinear Optics (A)

Prereq.: 6.014 or 8.07
G (2)
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 pulse generation and measurement techniques.
E. P. Ippen

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, devices, algorithms 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 with applications to artificial intelligence; optical interconnects; 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 1987-88**
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) (Revised Unit)

Prereq.: 6.014
G (2) **Next offered 1987-88**
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. Microwave FET's and IMPATT diodes, monolithic microwave integrated circuits. Alternate years.
H. A. Haus

6.642 Antennas and Radiation (A)

Prereq.: 6.014
G (2) **Not to be offered 1987-88**
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 8.08, 18.04 or *18.075*
G (1)
3-0-9

See description under subject 8.613J.
A. Bers, K. Molvig, 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, J. P. Freidberg

6.653J MHD Theory of Magnetic Fusion Systems I (A)

(Same subject as 22.615J)
Prereq.: 6.651J or 22.611J or 8.613J
G (1)
3-0-9

See description under subject 22.615J.
R. R. Parker

6.661 Receivers, Antennas, and Signals (A)

Prereq.: 6.014
G (2) **Not to be offered 1987-88**
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)
Prereq.: 6.014 or 8.03, 18.075
G (1) **Next offered 1987-88**
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. Method of characteristics. Varied applications.
J. R. Melcher

6.672 Continuum Electromechanics II (A)

Prereq.: 6.671
G (1) **Next offered 1987-88**
3-0-9

Laws, approximations, and relations of fluid 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. 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 1987-88**
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 and load management, and the impact of microprocessors. Alternate years.
F. C. Schweppe

6.685 Electric Machines (A)

Prereq.: 6.061 or 6.601
G (2) **Not to be offered 1987-88**
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 (Revised Content and Unit)

(6.150J)
(Same subject as 3.147J, 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.
R. T. Howe, C. G. Sodini, D. J. Edell
D. A. Rudman, C. V. Thompson
H. H. Sawin

6.720 Semiconductor Devices

Prereq.: 6.012
U (1)
4-0-8

The physics, modeling, fabrication, and application of selected semiconductor devices. Emphasis on devices in integrated circuit contexts. Introduces use of the energy band viewpoint. Topics: metal-oxide-semiconductor (MOS) devices including charge coupled de-

vices (CCDs) and MOSFETs; MOS logic and memory; planar diffused and lateral bipolar transistors; bipolar logic including current injection logic (I^2L); Schottky barriers, MESFETs and heterostructures.
C. G. Fonstad, Jr., C. G. Sodini

6.721 Contemporary Digital MOS Circuits

Prereq.: 6.032 or 6.004
U (1) **Not to be offered 1987-88**
3-0-9

Reviews and elaborates models of MOS transistors. Discusses scaling effects on device performance. Overview of organization and operation of contemporary MOS integrated circuits, especially microprocessors and static and dynamic RAMs. Uses circuit techniques to optimize speed/power tradeoffs. Systemic influences on device architectures and circuits.
R. E. Zippel

6.725 Solar Energy Systems

Prereq.: 6.002 or 6.071 or 2.02
U (1) **Next offered 1987-88**
3-0-9

Examines energy conversion systems, primarily solar. Topics: solar radiation, blackbody radiation; photovoltaic power generation including theory, materials, devices; systems analysis of solar heating, cooling, and hybrid electrical-thermal combinations; flat plate collectors, heat mirrors, heat transfer; alternate energy sources including photochemical, hydro, wind, and tidal power; energy storage systems. Guest lectures on topics of intensive current research. Elementary knowledge of thermodynamics helpful. Alternate years.
G. W. Pratt, Jr., R. D. Thornton

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

6.731J Physics of Solids I (A except VIII)

(Same subject as 8.231J)
Prereq.: 8.04 or 8.211, 6.018
G (1)
4-0-8

See description under subject 8.231J.
R. J. Birgeneau, M. S. Dresselhaus

6.732J Physics of Solids II (A)

(Same subject as 8.500J)
Prereq.: 6.730 or 6.731J
G (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.
M. S. Dresselhaus

6.734J Application of Group Theory to the Physics of Solids (A)

(Same subject as 8.513J)
Prereq.: 6.731J
G (1) **Not to be offered 1987-88**
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

6.741J Theory of Solids I (A)

(Same subject as 8.511J)
Prereq.: 6.732J
G (1)
3-0-9

See description under subject 8.511J.
D. Adler, J. D. Joannopoulos

6.742J Theory of Solids II (A)

(Same subject as 8.512J)
Prereq.: 6.741J
G (2)
3-0-9

Second term of a theoretical treatment of the physics of solids. Semiconductors: survey of band structures; effective mass theory; effective g-factor; transport; optical properties. Metals: band structures; electron dynamics; transport; magnetic properties; optical properties. Many body theory: the random phase approximation; collective effects in normal metals; Fermi liquid theory; superconductivity.
J. D. Joannopoulos, D. Adler, P. A. Lee

6.751 Quantum Electronics (A)

Prereq.: 6.731J 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 Microwave Magnetics (A)

Prereq.: 6.014 or 6.601
G (2) **Next offered 1987-88**
3-0-9

Introduces the propagation and mutual interaction of microwave photons, magnons, and phonons in ferro-, antiferro- and ferrimagnetic crystals. Elementary domain theory, including magnetic bubbles. Linear and nonlinear effects associated with magnetic resonance. Propagation of electromagnetic, magnetostatic and magnetoelastic waves in ferrite-loaded waveguides and thin ferrite films; reciprocal and non-reciprocal microwave circuit elements such as rotators, isolators, and circulators. Electromagnetic quantum-mechanical exchange and elastic channels of power flow. Alternate years.
F. R. Morgenthaler

6.762 Dielectric and Optical Materials and Devices (A)

Prereq.: 6.013
G (2) **Next offered 1987-88**
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 1987-88**
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 1987-88**
3-0-9

Topics selected from current device research areas. In recent years subject matter has included Schottky barriers and heterojunctions, charge coupled devices, surface acoustic wave devices, diode lasers, integrated and guided-wave optical components and circuits, and ultrahigh-speed transistors, including the permeable base transistor. 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.: 6.720, 6.150J
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, laser/electron beam 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.
C. G. Sodini, H. S. Lee

6.776J Plasma Processing in Integrated Circuit Fabrication (A)

(Same subject as 10.616J)
Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
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, graphoepitaxy 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 remaining 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 Concepts in Modern Programming Languages (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Core graduate subject in programming languages. Programming language concepts and design, with emphasis on abstraction mechanisms. Denotational semantics. Functional and imperative languages. Procedure call and parameter passing mechanisms. Generic and polymorphic definitions. Abstract data types. Efficiency issues. Several languages studied in detail, with attention given to design goals and interactions of features. Background in programming languages, compiler construction, and programming experience required.
J. V. Guttag, B. H. Liskov

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, R. Davis, 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 (1) **Not to be offered 1987-88**
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.: 6.035, 6.033
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)
3-0-9

See description under subject 18.404J.
D. A. Shmoys

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 Topics in Computer Systems Research (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Seminar on a selected research topic in the engineering of computer systems. Emphasizes software and hardware as a single system, and case studies of actual system implementations. Usually includes extensive reading in journals, discussion and preparation of reports. Content varies from year to year. Typical topics: information protection, design of physically distributed systems, and performance analysis. See instructor for topic to be offered. Limited enrollment.
J. H. Saltzer

6.847 Dataflow and Reduction Architectures (A)

Prereq.: 6.001, 6.032 or 6.004
G (1)
3-0-9

Dataflow and reduction models as bases for the organization of high performance and distributed computer systems. Suitability of functional languages for programming concurrent applications; data and demand-driven execution models and their relationship to lambda-calculus reduction rules. Streams and managers; dataflow program graphs; the unraveling interpreter. Static and dynamic dataflow architectures; sequential and parallel reduction machines. Parallel machines for logic programming.
Arvind

6.848J Theory of Parallel and VLSI Computation (A) (New)

(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) (New)

(Same subject as 18.436J)
Prereq.: 6.848J
G (2)
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.
L. Heath

6.852J Distributed Algorithms (A)

(Same subject as 18.437J)
Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
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 (1) **Next offered 1987-88**
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, data base 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
G (1)
3-0-9

See description under subject 18.415J.
R. L. Rivest

6.856J Algebraic Manipulation (A)

(Same subject as 18.429J)
Prereq.: 6.821, 18.063 or 18.310
G (2) **Next offered 1987-88**
3-0-9

Algorithms for computation with exact quantities: polynomial greatest common divisor and factorization, algebraic numbers and functions, elimination theory. Probabilistic algorithms for sparse polynomials. Integration and simplification of transcendental and algebraic functions, limits and orthogonal series. Additional discussion of representation and implementational issues in building computer algebra systems. Alternate years.
J. Moses, R. E. Zippel

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

6.866 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 Topics in Artificial Intelligence (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Seminar on selected, currently active research topics in artificial intelligence. One or two topics covered in depth each term. Intended primarily for advanced students in artificial intelligence but open to students with backgrounds in areas related to the topics discussed.
M. L. Minsky

6.871 Knowledge-Based Applications Systems (A)

Prereq.: 6.035, 6.034 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, mental poker, fair secret exchange. Polynomial-time statistical tests and algorithmic randomness. 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

6.880J Perspectives on Computers and Society (A)

(Same subject as STS 633J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Seminar on the interface between computers and society. Topics are: the influence of ideas derived from computers and computation on the individual's reconstruction of reality; modern society's dependence on computers; what the general public believes about computers and what computer scientists' role in creating beliefs about computers is and ought to be; questions of responsibility raised by large, possibly incomprehensible computer-based systems; ethical issues confronting computer scientists and engineers.
J. Weizenbaum

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

6.910 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)
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.
J. A. Tucker, K. J. O'Toole

6.922 Advanced VI-A Internship

Prereq.: 6.921
U (2, S)
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.
J. A. Tucker, K. J. O'Toole

6.925 Engineering Internship

Prereq.: —
U (1, 2, S)
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.
D. Adler

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, H. S. Marcus

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.
R. K. Lester, 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. G. Jansson

6.938 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

6.951 Graduate VI-A Internship

Prereq.: 6.922
G (1, S)
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.
J. A. Tucker, K. J. O'Toole

6.952 Graduate VI-A Internship

Prereq.: 6.951
G (1, 2, S)
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.
J. A. Tucker, K. J. O'Toole

6.955 Advanced Engineering Internship

Prereq.: 6.925
G (1, 2, S)
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)
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)
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)
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)
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. An initial letter of intent and a summary report must be submitted to 6.UR coordinator. 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.
D. Adler

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

7 Biology

7.UR Undergraduate Research

Prereq.: —
U (1, 2)
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.

7.01 General Biology

Prereq.: —
U (2) SD
4-0-8

Description of a variety of animals and plants (including parasites), organ systems, cell types, subcellular organelles, and macromolecular assemblies; metabolism of animals and plants; membranes, nucleic acid, and protein structure; an introduction to Mendelian and prokaryotic genetics; evolutionary ideas: the relationship of cell and organ structure to function; development of vertebrate, insect, and plant embryos; immunity in animals; neurobiology of simple systems.
V. M. Ingram

7.011 Introduction to Experimental Biology (Revised Unit)

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.
J. M. Buchanan, A. Torriani, L. A. Steiner, H-S. Shin

7.03J Genetics

(Same subject as 20.025J)
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, R. A. Fitts

7.031 Experimental Microbial Genetics

Prereq.: 7.011
U (2) **Next offered 1987-88**
2-16-6

Laboratory project in microbiology and genetics. 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. O. Hynes, R. Jaenisch, M. L. Pardue

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.
H. F. Lodish, B. J. Meyer

7.09 Cellular Neurobiology

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)
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 (1, 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.
Term 1: P. T. Matsudaira, B. Cochran
Term 2: 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, S. E. Luria

7.24 Topics in Bacteriology (A)

Prereq.: 7.21
G (1)
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, N. H. Hopkins, P. A. Sharp

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, L. P. Guarente

7.28 Topics in Nucleic Acid Biochemistry (A)

Prereq.: 7.03, 7.05
G (1)
3-0-9

Genome structure and function, emphasizing regulation of DNA transactions and protein synthesis in both prokaryotes 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

7.32 Analysis of Differentiation and Development

Prereq.: 7.05 or 7.33
G (2)
2-0-4

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.
D. Botstein, G. R. Fink

7.36 Advanced Neurophysiology (A)

Prereq.: 7.06
G (1)
3-0-6

A series of lectures, with student participation, on some aspects of the nervous system. Foundation for work on the structure and function of the nervous system.
J. Y. Lettvin

7.411-7.419 Seminars in Biological Oceanography (A)

Prereq.: —
G (1, 2)
Arr.

Selected topics in biological oceanography. Permission of instructor required. Information: A. L. Peirson (Woods Hole Staff).

7.421 Special Problems in Biological Oceanography (A)

Prereq.: —
G (1, 2)
Arr.

Advanced problems in biological oceanography with assigned reading and consultation. Information: A. L. Peirson (Woods Hole Staff).

7.43 Phytoplankton Ecology (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Overview of major algal classes, physiological processes, and large-scale systems as they relate to phytoplankton in the marine environment. Attention to interactions of environmental parameters (light, temperature, nutrients, trace metals, physical factors) on the growth and distribution of phytoplankton. Discusses multidisciplinary programs and modeling. Emphasizes current problems in the field through lectures, readings, and discussions. Students evaluate selected papers and present a seminar.
(Woods Hole Staff): D. M. Anderson, P. Glibert

7.44 Ecology of Oceanic Zooplankton

Prereq.: 7.43
G (2) **Next offered 1987-88**
3-0-6

Provides a general context for understanding current problem areas in oceanic zooplankton ecology. Major topics for lectures and demonstrations include zoogeography, behavioral and morphological adaptation to pelagic existence, secondary production and zooplankton energetics, and field and laboratory problems involved in their study. Opportunity for student participation in presenting material and in structuring portions of the course.
(Woods Hole Staff): N. Marcus

7.45 Benthic Ecology (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Aspects of the ecology of marine benthos. Includes communities, with consideration of sampling, life histories, population dynamics, biotic interrelationships, zoogeography, diversity, and evolution. Emphasizes recent literature including some historical perspective. Environments considered are shallow and deep-sea soft bottoms, sandy beaches, rocky shores, coral reefs, estuaries, and salt marshes.
(Woods Hole Staff): J. F. Grassle

7.46 Topics in Physiology and Biochemistry of Marine Animals (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

Features aspects of the metabolism, biochemistry, and physiology of marine animals. Particular emphasis on perception of, response and adaptation to, changing and varied conditions of the physical and chemical environment in the sea. Respiration and anaerobic metabolism, food and nutrition, osmoregula-

tion, thermal and pressure adaptation, chemoreception and foreign compound metabolism, and other topics considered. Special topics include light in the sea, locomotion and diving, cycles and migration.
(Woods Hole Staff): J. J. Stegeman, J. M. Capuzzo

7.491 Research in Biological Oceanography (A)

Prereq.: —
G (1, 2)
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 compositon 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)

7.51J General Physiology

(Same subject as 6.524J)
Prereq.: —
U (2) SD
3-0-9

Form-function relations. How local actions determine global geometry in development. Strategies of growth. Special problems in respiration, circulation, excretion, and animal movement illustrating how function and form direct each other. Structure and action of muscle. Physiology of perception. How the senses of predators affect the evolution of their prey. Mimesis and protective coloration of prey as guides to the nature of vision in predator. Tactics of color vision and form vision. Introduction to the physiology of nerve membrane and to the action of nervous tissue.
J. Y. Lettvin

7.52J Biotechnology of Mammalian Cells (New)

(Same subject as 10.56J, 20.803J)
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.
H. F. Lodish, A. J. Sinskey, D. I. C. Wang

7.53 Biological Electron Microscopy

Prereq.: 7.01
U (2)
2-2-5

Introduces the use of visualization techniques for studying biological structure. Operation of the transmission and scanning electron microscopes. Biological sample preparation including negative staining, shadowing, Kleinschmidt technique for nucleic acids, embedding and sectioning, autoradiography, and specific antibody staining. Interpretation of ultrastructure from micrographs. Limited to 16 students.
J. A. King, E. A. Hartwieg

7.54J Human Physiology

(Same subject as 20.022J)
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 (New)

(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 men and women's lives 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

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

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

7.66 Cellular and Molecular Biology of the Nervous System (New)

Prereq.: —
G (2)
2-0-4

Graduate discussion seminar in molecular neurobiology. Includes: release and reception of neurotransmitters; voltage and ligand-gated channels; neural induction and determination; cellular migration and differentiation; neuronal growth factors; synaptogenesis; neuropeptides; modulation of synaptic function; axonal transport; biochemistry and physiology of phototransduction; cell adhesion-axon growth and guidance; Drosophila retina. Discussions focus on critical appraisal of current published papers in the field.
S. J. Burden, R. D. G. McKay

7.71J Biophysical Chemistry

(Same subject as 5.64J)
Prereq.: 5.60, 7.05
U (1)
3-0-9

Nucleic acids: structures and forces which 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.
P. R. Schimmel, G. A. Petsko

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, L. A. Steiner

7.75J Advanced Biochemistry (A)

(Same subject as 5.50J)
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, C. T. Walsh

7.77 Structure and Function of Proteins and Nucleic Acids (A)

Prereq.: Permission of Instructor
G (1)
4-0-8

Studies of proteins, nucleic acids, their interactions, and their assembly into large complexes. Biochemical and physical principles underlying enzyme mechanism and macromolecular structure and function. The use of chemical, enzymatic, genetic, and physical methods in the analysis of tertiary and quaternary interactions. Symmetry, design, and assembly principles used by viruses, chromosomes, and cytoskeletal arrays.
U. L. RajBhandary, P. R. Schimmel, F. Solomon

7.78 Seminar in Lipid and Carbohydrate Biochemistry (A)

Prereq.: 7.05
G (2)
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

7.86 Molecular Genetics (A)

Prereq.: 7.05, 7.27
G (2)
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 of critically evaluating papers. 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)
Arr.

Class work in various fields of biology not covered by the regular subjects of instruction. Consult Department headquarters.

7.941 Research Problems (A)

Prereq.: —
G (1)
Arr.

7.942 Research Problems (A)

Prereq.: —
G (2)
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

8 Physics

General Undergraduate Subjects

8.UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in physics. For further information contact the Departmental UROP Coordinator.
R. P. Redwine

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. Heat and an introduction to kinetic theory.
Term 1: *S. B. Kowalski*
Term 2: *A. P. French*

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.
J. W. Dreher

8.02 Physics II

Prereq.: 8.01 or 8.012; 18.01
U (1, 2)
5-0-7

Introduction to Electromagnetism 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.
Term 1: *J. L. Matthews*
Term 2: *A. P. French*

8.021 Physics II

Prereq.: 8.01 or 8.012, 18.01
U (2)
5-0-7

Intended for students who wish a broader view of physics in their second semester, with more emphasis on conceptual understanding and less on mathematical details. Electrostatics, electric currents, magnetic fields, Maxwell's equations and light, elements of the quantum theory, the Bohr atom, introduction to nuclear and particle physics. May be followed by 8.03 without too much difficulty.
V. Kistiakowski

8.022 Physics II

Prereq.: 8.012
U (2)
5-0-7

Parallel to 8.02, but at a mathematically more advanced level. 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; reflexion and refraction; phase and group velocity. Optics; wave solutions to Maxwell's equations; polarization; Snell's Law, interference, Huygens' principle, Fraunhofer diffraction, gratings.
Term 1: *G. Bekefi*
Term 2: *A. P. French*

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: *C. J. Horowitz*
Term 2: *E. H. Farhi*

8.044 Statistical Physics I

(8.204)
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.
T. J. Greytak

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: *E. H. Farhi*
Term 2: *C. R. Canizares*

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.
P. C. Joss

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.
M. W. P. Strandberg

8.08 Statistical Physics II (Revised Content)

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: Noninteracting 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 (2) LAB
1-6-5

A project laboratory in which students develop experiments of their own selection, by themselves, with close faculty guidance. Instruments, computers, and associated facilities available to construct and run experiments in many areas of physics: electron and ion physics; mechanics; optics, spectroscopy, acoustics, electronics, and nuclear and cosmic-ray physics. Computer-controlled projects available. 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 6 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.
A. J. Lazarus

8.19 Readings in Physics

Prereq.: —
U (1, 2)
Arr.

Supervised reading and library work. Choice of material and allotment of time according to individual needs. For students finding it desirable to do work not provided for in the regular subjects. Specific approval required in each case.
A. J. Lazarus

Undergraduate Elective Subjects

8.20 Introduction to Special Relativity

Prereq.: *8.01, 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. F. Taylor

8.206J Public Controversies on the Control of Technology

(Same subject as STS 413J)
Prereq.: —
U (2) HASS **Next offered 1987-88**
2-0-7

See description under subject STS 413J.
B. T. Feld, C. Weiner

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.
R. K. Lester, 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.
D. Adler

8.22 Computational Physics (Revised Unit)

Prereq.: 8.04 or 8.211, 8.05
U (2)
2-2-8

Fundamental techniques of computational physics are developed through solution of a sequence of physics problems: semiclassical quantization of molecular vibrations, order and chaos in two-dimensional classical motion, stationary and time-dependent solutions of the Schroedinger equation, Born and Eikonal ap-

proximations to quantum scattering, inversion of electron scattering cross sections, solution of the two-dimensional Poisson equation, propagation of shock waves in one dimension, and the two-dimensional Ising model.
J. W. Negele

8.231J Physics of Solids I

(Same subject as 6.731J)
Prereq.: 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. The second half of this sequence, 8.500J, is listed among the graduate subjects.
R. J. Birgeneau, M. S. Dresselhaus

8.236 Topics in Quantum Theory of Matter

Prereq.: 8.05
U (2) **Next offered 1987-88**
3-0-9

Introduces group theory and the quantum mechanics of atoms, molecules, and crystals. Group representations. The full rotation group and angular momentum. Addition of angular momentum and the Clebsch-Gordan coefficients. Approximate atomic wave functions, spin-orbit interaction, and hyperfine structure. Molecular electronic wave functions. Normal modes of vibration. Molecular rotation. Symmetry properties of crystals and the group of the k-vector; Crystalline electric fields.
M. W. P. Strandberg

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 1987-88**
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 **Not to be offered 1987-88**
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 1987-88**
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 (protons, neutrons, hyperons), the properties and interactions of these particles are established. Quantum numbers and multiplet structure of particle families. Nuclei as multibaryon systems: stability, excited states, fission and fusion processes. Nuclear matter, neutron stars, and exotic forms of matter.
J. L. Matthews

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.
J. W. Dreher

8.284 Modern Astrophysics

Prereq.: 8.04, 8.204, *8.05*
U (1)
3-0-9

Applications of physics (Newtonian, statistical, and quantum mechanics) to fundamental processes which 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. Van Dorn Bradt

8.286 The Early Universe

Prereq.: 18.03, 8.02
U (2) SD **Next offered 1987-88**
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, L. M. French

8.291J Planetary Science I

(Same subject as 12.131J)
Prereq.: *8.03*
U (1) SD
3-0-9

See description under subject 12.131J.
D. C. Jewitt, C. C. Counselman

8.292J Planetary Science II

(Same subject as 12.132J)
Prereq.: 12.131J or 8.291J
U (2) SD
3-0-9

See description under subject 12.132J.
D. C. Jewitt, J. Wisdom

8.293J Dynamical Astronomy

(Same subject as 12.133J)
Prereq.: 18.03
U (2) SD
3-0-9

See description under subject 12.133J.
C. C. Counselman

8.299 Physics Teaching

Prereq.: —
U (1, 2)
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.
A. J. Lazarus

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.
M. W. P. Strandberg

Graduate Subjects

An asterisk (*) denotes subjects not routinely offered but that can 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.
K. Huang

8.321 Quantum Theory I (A)

Prereq.: 8.07
G (1)
4-0-8

8.322 Quantum Theory II (A)

Prereq.: 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.
K. A. Johnson

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

Thermodynamics: work and heat, temperature and entropy. Basic postulates of statistical mechanics, classical and quantum mechanics. Open systems: canonical and grand canonical distributions and free energy minimum principle. Applications to real and model systems: Fermi and Bose gases, photon gas, lattice vibrations, Van der Waal gases. Fluctuation-dissipation theorem. Monte Carlo methods. 8.334 a continuation of 8.333. Superfluidity. Elementary excitations in Bose and Fermi systems. Broken symmetry and phase transitions: scaling description and the application of the renormalization group to critical phenomena.
A. N. Berker

8.361 Quantum Theory of Many-Particle Systems (A)

Prereq.: 8.322, 8.333
G (1) **Not to be offered 1987-88**
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.
B. 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)
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)
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. E. Pritchard

8.432 Physics of Random Processes (A)

Prereq.: 8.05, *8.08*
G (2) **Not to be offered 1987-88**
3-0-9

Mathematical description of random processes; joint probability distributions, correlation functions, and power spectra. Fluctuations in discrete systems: shot noise, photon counting. Fluctuations about thermal equilibrium: space-time correlations of fluctuations of density, entropy, pressure, and their relations to transport coefficients and dissipation constants. Applications to properties and detection of light extensively discussed, including principles of interference, spatial coherence, and digital auto-correlation.
J. D. Litster

8.451 Elements of Quantum Electronics (A)

Prereq.: 8.05, 8.07
G (1) **Next offered 1987-88**
3-0-9

Introduction of dipolar interaction of radiation with matter, first in classical terms, followed by treating the matter quantum mechanically, giving a modern view of theory of radiation as applied to lasers. Nonlinear processes leading to laser master equations introduced and their consequences analyzed. Coherent interaction processes, pulse propagation, and Doppler-free resonances treated. A review of high-energy lasers and the related topics presented. Lecture demonstrations given.
A. Javan

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.

8.500J Physics of Solids II (A)

(Same subject as 6.732J)
Prereq.: 6.730 or 6.731J or 8.231J
G (2)
4-0-8

See description under subject 6.732J.
M. S. Dresselhaus

8.511J Theory of Solids I (A)

(Same subject as 6.741J)
Prereq.: 8.231J
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. D. Joannopoulos

8.512J Theory of Solids II (A)

(Same subject as 6.742J)
Prereq.: 8.511J
G (2)
3-0-9

See description under subject 6.742J.
J. D. Joannopoulos

8.513J Application of Group Theory to the Physics of Solids (A)

(Same subject as 6.734J)
Prereq.: 8.500J
G (1) **Not to be offered 1987-88**
3-0-9

See description under subject 6.734J.
M. S. Dresselhaus

8.532 Physics of Semiconductors (A)

Prereq.: 8.231J or 8.05
G (2)
3-0-9

Theoretical and experimental exposition of the electrical, optical, and magnetic properties of semiconductors. Topics: Energy bands, emphasizing $\vec{k} \cdot \vec{p}$ theory; cyclotron resonance; magnetotransport; interband and intraband optics, impurity states; elementary excitations, phonons, excitons, polaritons, plasmons, electron-hole drops; nonlinear spectroscopy, two-photon absorption, Raman scattering; two-dimensional systems, superlattices, quantum wells, quantized Hall effect; physics of devices, i.e., tunneling, electron transfer, avalanche, lasers.
R. L. Aggarwal

8.562 Correlations and Critical Behavior in Condensed Matter (A)

Prereq.: 8.511J, 8.333
G (2) **Next offered 1987-88**
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.
R. J. Birgeneau

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.
A. Bers, K. Molvig, M. Porkolab

8.614J Introduction to Plasma Physics II (A)

(Same subject as 6.652J, 22.612J)
Prereq.: 6.651J or 8.613J or 22.611J, 18.075
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)
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 couping, 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 1987-88**
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 Temperature Plasmas I (A)

Prereq.: 8.613J
G (1) **Not to be offered 1987-88**
3-0-9

8.642 Physics of High Temperature Plasmas II (A)

Prereq.: 8.613J
G (1) **Next offered 1987-88**
3-0-9

Basic concepts of plasmas, with temperatures of thermonuclear interest, relevant to fusion research and to astrophysics. Microscopic transport processes due to inter-particle collisions and to 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

Introduction to nuclear phenomena; analysis of the various modes of excitation, and associated degrees of freedom as revealed by a broad range of experimental observation; experimental support for the shell model, and the microscopic origin of independent particle motion. Nuclear collective motion as manifest in rotation and vibration; Giant Resonances. Mesonic degrees of freedom and their role in nuclear forces and electromagnetic currents. Evidence for quark and gluon substructure in high energy lepton scattering.
R. P. Redwine

8.711 Nuclear Physics I (A) (Revised Content and Unit)

Prereq.: 8.321, 8.710
G (1)
4-0-8

8.712 Nuclear Physics II (A) (Revised Content and Unit)

Prereq.: 8.711
G (2)
4-0-8

Comprehensive course in experimental foundations and theoretical understanding of nuclear structure and reactions, emphasizing the role of single nucleon, collective, mesonic, and quark degrees of freedom. Substructure of nuclei and hadrons revealed by electromagnetic probes. Nuclear shell model and hadron quark model. Experimental studies of nuclear interactions, and theories based on mesons and quarks. Mean field theory of nuclear structure, collective motion, and dynamics. Reaction theory and study of nuclear structure through scattering of nucleons, nuclei, leptons and mesons. Introduction to relevant aspects of QCD. Study of quark and gluon degrees of freedom using deep inelastic lepton scattering and relativistic heavy ion collisions. Aspects of nuclear astrophysics.
J. W. Negele, J. Polonyi

8.731 Nuclear Physics Seminar (A)

Prereq.: 8.322, 8.712
G (1, 2)
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.
A. M. Bernstein, J. W. Negele, R. P. Redwine

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.: 8.05, 8.321
G (2)
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 (1)
3-0-9

New experiments and data. New machines, detectors, technologies; p-p̄ 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.
L. S. Osborme

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. Information: G. W. Clark.

8.911 Astrophysical, Space, and Laboratory Plasmas, Theoretical Foundations and Comparative Study (A)
(New)

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, elements of turbulence theory.
S. Olbert

8.913 Physics of Space Plasmas I (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-9

8.914 Physics of Space Plasmas II (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
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, bowshock, 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 1987-88**
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 1987-88**
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' 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: J. Tonry.

8.923 High-Energy Astrophysics (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
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.
E. Bertshinger

8.942 Cosmology (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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. Information: G. W. Clark.

8.952 Particle Physics of the Early Universe (A)
(New)

Prereq.: 8.323, 8.324
G (2) **Not to be offered 1987-88**
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. Guth

8.962 General Relativity and Gravitation (A)*

Prereq.: 8.07
G (1) **Not to be offered 1987-88**
3-0-9

Special relativistic electrodynamics and hydrodynamics. Principle of equivalence. Tensor calculus for general coordinate systems. Riemannian geometry. Gravitational field. Einstein field equations. The Einstein action. Schwarzschild solution. Solar system tests. Gravitational radiation. Robertson-Walker metric and cosmography. Standard cosmological model. The early universe. Black holes.
J. Goldstone

8.981, 8.982 Selected Topics in Astrophysics (A)*

Prereq.: Permission of Instructor
G (1, 2)
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

9 Brain and Cognitive Sciences

9.UR Undergraduate Research

Prereq.: —
U (1, 2, S)
Arr.

Individual participation in an ongoing research project in brain science, experimental psychology, and cognition. For students in the Undergraduate Research Opportunities Program.
J. M. Wolfe

9.00 Introduction to Psychology

Prereq.: —
U (1) HASS
4-0-5

A survey of the science 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)
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 Humanities Requirement *only* by students concentrating in Psychology; see Department for details.
G. E. Schneider, E. Bizzi, P. H. Schiller

9.014J The Human Nervous System: The Neurosciences I (A)

(Same subject as 20.511J, HST 130J)
Prereq.: Permission of Instructor
G (1)
6-3-6

See description under subject HST 130J.
A. M. Graybiel, M. P. Alexander, E. Bizzi, V. Chan-Palay, M. A. Moskowitz, R. A. North, S. Palay, T. Sabin, P. H. Schiller, H. R. Tyler, R. S. Williams, R. J. Wurtman

9.015J The Neurosciences II (A)

(Same subject as 20.512J)
Prereq.: Permission of Instructor
G (2)
6-0-9

See description under subject 20.512J.
R. J. Wurtman, M. R. Rosner, S. H. Corkin, R. McKay, W. G. Quinn, G. E. Schneider

9.019 Topics in Neuropsychology (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
4-0-6

Introduces current research on the effects of brain disease on human behavior. Lectures by neuropsychologists, neurologists, and psychiatrists, emphasizing 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. H. Corkin, Guest Lecturers

9.021 Topics in Brain and Behavior (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

Detailed discussion of the neuroanatomy, neurochemistry, neurophysiology, and neuropsychology of selected regions of the forebrain. Seminar sessions in which participants take turns leading class discussions on the readings and presenting reports on special topics. Occasional clinical demonstrations during the term and a final test during the last class. Alternate years.
S. H. Corkin, A. M. Graybiel

9.022 Biochemical Neuroanatomy (A)

Prereq.: 9.014J
G (2) **Next offered 1987-88**
3-0-6

Focuses on recent findings and functional concepts dealing with neurotransmitter systems in the central nervous system. Includes lectures and seminar sessions in which student participants take turns leading class discussions and presenting reports. Alternate years. Permission of instructor required; HST 130 or equivalent is recommended.
A. M. Graybiel

9.023 Principles of Neuronal Growth

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

Topics in developmental neurobiology including neuronal proliferation, cell lineages, initiation of neuritic outgrowth, structure of growing axons, theories of axon guidance, growth factors and growth-associated proteins, synaptogenesis, role of activity in formation of connections, aberrant axonal growth and behavioral disorders, hormones and development. Requirements include readings in recent literature, participation in class discussions, and short reports. Alternate years.
G. E. Schneider, S. Jhaveri, Guest Lecturers

9.036 The Visual System (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-6

Reviews the current neurophysiological and neuroanatomical research literature on the mammalian visual system. Alternate years.
P. H. Schiller

9.05 Psychotechnology: Scientific and Ethical Issues in Behavior Control

Prereq.: —
U (1) HASS **Next offered 1987-88**
3-0-6

The behavior of animals — including human beings — can be altered in various ways through the use of physical methods and chemical agents. Discusses biomedical and psychotechnological approaches to delinquency, drug addiction, and other social problems in terms of their alleged scientific bases, scope, power and limitations. Emphasizes throughout questions bridging the traditional gaps between science, technology, and social policy.
S. L. Chorover

9.051 Human Nature and Sociobiology (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-6

Critical survey of attempts to account for human social behavior in terms of evolutionary and psychobiological mechanisms. The "nature vs nurture" controversy and its influence from ancient times to the present. Particular emphasis on motivation, territoriality, aggression, competition, cooperation, etc. and alleged implications for laissez-faire and planned economic systems, conformity and deviance, social stability and social change. Readings in scholarly and popular sources.
S. L. Chorover

9.06 Conflicting Images of Humanity and Nature (New)

Prereq.: —
U (1) HASS
3-0-6

Nearly five billion, and growing, we humans are straining the earth's natural resources to an unprecedented degree. Ancient images of relations between humanity and nature were overturned by the founding fathers of modern science and technology who saw themselves as detached from and in conflict with nature. How does such imagery relate to our current environmental crisis? This question is considered in historical perspective and in light of recent developments in physics, psychology, ecology, and feminist theory.
S. L. Chorover

9.30 Animal Behavior

Prereq.: 9.00
U (1) HASS
3-0-6

Reviews basic concepts in the study of animal behavior. Examines the natural history of selected species (e.g., felids, canids, and cephalopods). Contributions of environment and heredity to the shaping of behavior. Inquires into the contribution of behavior to meeting requirements for individual and species survival. Analyzes selected problems including animal communication, navigation, sexual behavior, aggression, defense, perception and learning.
A. Hein

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, etc. 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) **Not to be offered 1987-88**
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. Core 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, R. Held

9.36 Natural Computation and Control

Prereq.: 9.35 or 9.62J, 18.02
U (1)
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)
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

9.366 Computer Graphics and Vision

Prereq.: 4.241 or 9.36
U (2)
3-0-6

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 antialiasing, tiling, solid-modeling, shading, raytracing, color, texture, motion blur, and animation. Surfaces of particular interest are clouds, water, rocks (fractals), and trees. For graduate "A" credit, register in 9.363.
W. A. Richards, B. M. Dawson

9.370 Control of Movement in Biological and Robotic Systems (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-6

Synthesizes recent approaches toward motor control in the fields of neurophysiology, artificial intelligence, and systems theory. Topics: understanding the physical plant in biological and artificial systems. Kinematics, statics, dynamics. Actuators and effectors. Control of unconstrained movements: open loop control and trajectory determination. Feedback control and reflexes. Control of constrained movements: handwriting, manipulation, and locomotion. Alternate years.
J. Hollerbach, E. Bizzi

9.372 Movement: Mechanisms and Models (A)

Prereq.: 9.370
G (1) **Not to be offered 1987-88**
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. Permission of instructor required for students without 9.370 background. Alternate years.
J. Hollerbach, E. Bizzi

9.380 Visual Information Processing: from Computational Theory to Neuronal Mechanisms (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Study of biological vision from the perspectives of computation, psychophysics, neuroscience, and biophysics, within the framework of information processing. Examines algorithms for solving vision problems; neuronal and biophysical models of visual computations; and the use of psychophysical and physiological data to test and modify computational models. Includes: photometry, edge detection, motion, stereo, regularization theory, neuronal models, and biophysical mechanisms.
T. A. Poggio, S. Ullman, C. Koch, E. Hildreth

9.382 Seminar on Visual Information Processing (A)

Prereq.: Permission of Instructor
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, hardware for computer vision, and biological mechanisms of vision. Centers around ongoing work by participants and presentations by them.
T. A. Poggio, S. Ullman

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 Psychology

Prereq.: Permission of Instructor
G (2)
4-0-8

Survey of theories, methods, and findings in cognitive psychology. Includes pattern recognition, imagery and mental codes, memory and attention, and language comprehension and production.
M. F. Garrett, S. E. Carey, S. Pinker, M. C. Potter

9.50 Research in Psychology

Prereq.: 9.00 or 9.62J or 9.90; and one other subject in Course IX
U (1, 2, S) LAB
2-8-2

Laboratory research in the areas of perception, learning, memory, and development. Each student carries out an experimental study in one of these areas 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.
M. F. Garrett

9.591 Seminar in Psychology of Language and Communication I (A)

Prereq.: 9.59 or 9.901
G (1) **Next offered 1987-88**
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 sub-human 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.
M. F. Garrett

9.592 Seminar in Psychology of Language and Communication II (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
3-0-6

Advanced topics in psycholinguistics, emphasizing current studies of language production and language disorders. A research paper required as part of this subject. Alternate years.
M. F. Garrett

9.601 Seminar on Language Acquisition (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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.
S. Pinker

9.605 Seminar on Spatial Cognition (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
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, S. E. Carey, M. C. Potter

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

9.63 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, M. F. Garrett

9.632 Theory of Machine Inductive Inference

Prereq.: 9.62J
G (1)
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

9.641 Cognitive and Language Development (A)

Prereq.: 9.62J or 24.116J
G (1) **Next offered 1987-88**
3-0-6

Introduction at an advanced level to the development of language and cognition in the child. Emphasis on connections between developmental psychology and cognitive psychology, linguistic theory, and history and philosophy of science. Combines survey lectures on each topic with seminar discussions of contemporary research. Permission of instructor required in addition to 9.62J or 24.116J. Alternate years.
S. E. Carey, S. Pinker

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

9.671J Problems of Mental Representation (A)

(Same subject as 24.518J)
Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 24.518J.
N. Block

9.68 Affect: Biological, Psychological, and Social Aspects of "Feelings"

Prereq.: 9.00
U (2) HASS
3-0-6

What is affect? This seminar addresses this question in an effort to make an important aspect of human experience comprehensible. Considers the nature of affect and traces both its development within the individual human being and its connections with various cognitive and behavioral variables. Reviews some relevant features of brain organization. Examines some familiar aspects of human culture to determine the extent to which they may properly be regarded as socially organized counterparts of individual feelings.
S. L. Chorover

9.70 Social Psychology

Prereq.: —
U (2) HASS
3-0-6

Examines the basic processes by which people interact with, perceive, and make judgments of others, influence each other and develop social beliefs and values, in the context of small and large groups and societies.
S. L. Chorover

9.75J Psychology of Gender

(Same subject as SP 460J)
Prereq.: —
U (2) HASS **Next offered 1987-88**
3-0-6

9.751J Psychology of Gender

(Same subject as SP 461J)
Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

Examines evidence (and lack thereof) for differences in the ways in which 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 Development of Behavior

Prereq.: 9.00 or 9.62J
U (2) HASS
3-0-6

History of the changing concepts of infancy, childhood and development. Interaction of innate and experiential factors in the development of learning capacities, perception, social behavior and motor patterns in both animals and humans. Implications of evolution, genetics, embryology and early experience for the ontogeny of behavior.
A. Hein

9.90 Human Development: Individual and Social Perspectives

Prereq.: —
U (2) HASS
3-0-6

Examines psychological processes and structures from a developmental perspective. Aspects of sensorimotor, perceptual, cognitive, social and personality development are traced from infancy to adulthood. Focuses on the accurate description of what changes with age and of the respective roles of nature and nurture in determining the child's course of development.
D. N. Osherson

9.901 Proseminar in Psychology (A)

Prereq.: Permission of Instructor
G (1)
6-0-6

General introduction to graduate work in psychology and brain science, to be taken in conjunction with other, more specialized subjects depending upon student's background and interests. Restricted to Course IX graduate students. Consult E. Bizzi.

9.91, 9.92 Topics in Psychology

Prereq.: 9.00 or 9.62J and any other two subjects in Psychology
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 Psychology (A)

Prereq.: Permission of instructor
G (1, 2, S)
Arr.

Opportunity for graduate study of advanced subjects in psychology not included in other subject listings. Programs subject to approval of professor in charge. Consult M. F. Garrett.

9.921 Research in Psychology (A)

Prereq.: 9.901
G (1)
Arr.

9.922 Research in Psychology (A)

Prereq.: 9.901
G (2)
Arr.

9.923 Research in Psychology (A)

Prereq.: 9.901
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. F. Garrett.

9.931 Research Reports (A)

Prereq.: 9.901
G (1)
0-0-6

9.932 Research Reports (A)

Prereq.: 9.901
G (2)
0-0-6

9.933 Research Reports (A)

Prereq.: 9.901
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. F. Garrett.

10.UR Undergraduate Research

Prereq.: —
U (1, 2)
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 a S.B. thesis; to be arranged by the student and appropriate MIT faculty member.
C. M. Mohr

10.01 Engineering Concepts and Computer Methods

Prereq.: —
U (1, 2)
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, data base management, and numerical programming.
L. B. Evans, M. A. Kramer, C. M. Mohr, U. W. Suter

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 (Revised Content)

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

10.14 Chemical Engineering Thermodynamics II (Revised Content)

Prereq.: 10.01, 10.13
U (2)
3-0-6

Extension of 10.13, intended primarily for chemical engineering majors. Thermodynamics of multi-component 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, H. H. Sawin

10.19 Experimental Methods in Combustion and Heat Transfer

Prereq.: 10.302, 10.37
U (2) **Next offered 1987-88**
2-8-2

Students receive instructions on methods of measurements of temperatures and radiative heat transfer, in high temperature reacting systems, on collection and analyses of representative gas and solid samples, measurement of gas and particulate velocities and in general, the characterization of particulate clouds and fuel sprays. Working in small teams students are assigned projects preferably relating to ongoing research programs. Enrollment limited. Permission of instructor required.
J. M. Beér

10.21 Structures and Properties of Matter

Prereq.: 5.11, 5.62
U (1)
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.
U. W. Suter, C. K. Colton

10.24 Principles, Processes, and Synthesis in Industrial Chemistry (A)

Prereq.: 10.37, 10.32
G (2)
3-0-6

Studying factors determining flowsheets, equipment design, internal interactions in plants for producing industrial chemicals. Case studies for variety of organic/inorganic chemicals used to demonstrate application of engineering principles in analysis and synthesis of process flowsheets. Examples illustrate impacts of raw material availability, reactor design developments, new process chemistry, and process economics. Extensive problem work on influence of stoichiometry, energy requirements, kinetics, and transfer processes.
M. P. Manning

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. Emphasizes applications of engineering concepts and fundamentals to solution of practical and research problems. Training in planning research projects, execution of experimental work, and articulation (both oral and written) of the research plan and results in the areas of applied chemical technology and engineering operations related to mass, momentum, and heat transfer.
R. F. Baddour, D. J. Goldstein, M. P. Manning

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 to reinforce theoretical background gained during formal classroom tutoring by providing practical appreciation for operational characteristics of different processes. Some emphasis given to developing oral and written communication skills.
D. J. Goldstein, T. A. Hatton, M. P. Manning

10.28J Multivariable Control Systems I (A)

(Same subject as 2.154J, 6.233J, 13.47J, 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.
Geo. 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, 13.48J, 16.342J)
Prereq.: 10.28J
G (2)
4-0-8

See description under subject 6.234J.
Geo. Stephanopoulos, M. Athans, J. K. Hedrick, M. S. Triantafyllou, L. Valavani

10.301 Fluid Mechanics

Prereq.: 18.03
U (1)
3-0-6

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

10.302 Transport Processes

Prereq.: 10.13, 10.301
U (2)
3-0-6

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.
Greg Stephanopoulos

10.32 Separation Processes (Revised Content)

Prereq.: 10.14, 10.302
U (1)
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 Processes (A) (Revised Content)

Prereq.: 10.301, 18.03
G (1)
3-0-6

Introduction to mathematical techniques for handling transport and rate problems basic to most chemical engineering processes. Polyadics, tensors, and curvilinear coordinate systems. First and second order partial differential equations arising in physical applications. Solution by various analytical techniques including separation of variables and integral transforms. Approximate solutions by perturbation methods.
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; numerical methods for tracking multiple-steady and time-periodic states.
R. A. Brown

10.34 Numerical Methods Applied to Chemical Engineering (A)

Prereq.: 10.33
G (2)
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 (2) **Next offered 1987-88**
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 and discusses real process design problems, with case studies in chemical processing and petrochemicals. Emphasizes conception and invention of processes, as well as analysis and economic balances, to specify optimum design and operating conditions. Discusses a variety of cases throughout the term.
Geo. Stephanopoulos

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, multi-step 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)
2-2-4

Introduces techniques for computer-aided analysis of chemical processing systems. Development of mathematical models to describe dynamic and steady-state process behavior. Numerical methods for solving resulting systems of nonlinear differential and optimization problems. Numerical techniques for solving the resulting 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) **Next offered 1987-88**
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.
Geo. 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 to 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 by permission of instructor.
J. B. Howard, J. P. Longwell

10.40 Chemical Engineering Thermodynamics (A)

Prereq.: 10.13
G (1, 2)
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. Applications emphasized through extensive problem work relating to practical cases.
J. W. Tester

10.42 Advanced Thermodynamics (A)

Prereq.: 10.40
G (2)
2-0-6

Equilibrium and stability concepts examined in depth for multicomponent, multiphase systems. Equations of state for pure components and mixtures, electrolytes and non-electrolytes. Surface thermodynamics, equilibrium in body force fields, irreversible and statistical thermodynamics comprise other topics.
J. W. Tester

10.48J Gas-Solid Reactions (A)

(Same subject as 3.551J)
Prereq.: 3.55, 10.50
G (2) **Next offered 1987-88**
3-0-6

See description under subject 3.551J.
J. Szekely

10.49J Biomedical Transport Phenomena (A)

(Same subject as HST 521J)
Prereq.: 10.301, 10.302
G (2)
2-0-5

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, M. L. Yarmush

10.50 Heat and Mass Transfer (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 fluids. 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)
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, etc.
R. C. Armstrong

10.515 Structural Theories of Polymer Fluid Mechanics (A)

Prereq.: 10.301
G (1) **Next offered 1987-88**
3-0-6

Structural and molecular models for polymeric liquids. Non-equilibrium 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) (New)

(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) (New)

Prereq.: Permission of Instructor
G (1)
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 (New)

(Same subject as 7.52J, 20.803J)
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.
H. F. Lodish, 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)
3-0-6

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, to whole-cell metabolism, to pure and mixed population dynamics and stability, to full bioreactor 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.
Greg Stephanopoulos, A. J. Sinskey

Biochemical Engineering

10.58 Structure, Dynamics, and Reactivity in Molecular and Cellular Biology (New)

Prereq.: —
G (1)
2-0-4

Overview of basic physical biochemistry and interaction of biology and chemical engineering. Structure, conformation, and function of biological macromolecules emphasizing proteins. Prokaryotic and eukaryotic cell properties and relationship to cell function. Other topics: adsorption and denaturation of proteins, cellular transport processes, interfacial phenomena in biology, applied immunology. Biophysical and biochemical phenomena considered with an eye toward biotechnological processes.
M. L. Yarmuch

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.: 5.62 or 10.37
G (1)
3-0-6

Relationships of activity and selectivity to physical and chemical properties of a solid catalyst. Physical adsorption, chemisorption. Kinetic models and correlation of rate data. Components and preparation of catalysts. Physical characterization and examination of catalyst structures. Supported metal catalysts, acid catalysts and zeolite catalysts, catalytic oxidation. Processing of petroleum and hydrocarbons. Synthesis gas and associated processes. Experimental methods.
C. N. Satterfield

10.611J Microelectronics Processing Technology (New)

(Same subject as 3.147J, 6.701J)
Prereq.: 10.615
U (1, 2)
3-4-5

See description under subject 3.147J.
H. H. Sawin, C. G. Sodini, D. J. Edell
D. A. Rudman, C. V. Thompson,
R. T. Howe

10.615 Integrated Circuit Processing (A)

Prereq.: 10.302
G (1) **Next offered 1987-88**
3-0-6

Introduces the basic process techniques used in silicon monolithic integrated circuits. Reviews fundamental solid-state chemistry and physics. Introduces basic semiconductor device physics. Prime emphasis on application of transport phenomena, thermodynamics, chemical kinetics, process design, and process control to integrated circuit processing. Topics include crystal growth, chemical vapor deposition, oxidation, etching, lithography, dopant diffusion, metallization.
H. H. Sawin

10.616J Plasma Processing in Integrated Circuit Fabrication (A)

(Same subject as 6.776J)
Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-9

See description under subject 6.776J.
H. H. Sawin, L. R. Reif

10.63 High-Technology Separations Laboratory

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
2-5-5

Biomedical/biochemical solutes (hormones, enzymes, proteins, etc.): their separation, purification, harvesting via ultrafiltration, reverse osmosis, ion exchange, high-performance liquid chromatography, and affinity methods. Coupling of processes, recycles, detection/control/validation, scale-up visits to study large scale processes.
E. W. Merrill

10.641 Molecular and Morphological Engineering of Polymers (A)

Prereq.: —
G (2)
3-0-6

Introduces structure and properties of polymers. Describes macromolecular architecture and morphologies of solid polymers. Polymer surfaces and interfaces. Properties covered include thermal transitions, transport properties, solid-state mechanical behavior. Also discusses the effects of various non-polymeric additives.
R. E. Cohen

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 non-catalytic, catalytic and electrocatalytic reaction systems. Reactor stability and sensitivity to operating parameters. Choice and design of reactors for heterogeneous reactions.
R. F. Baddour, J. B. Howard, A. F. Sarofim

10.651J Fluidization (A)

(Same subject as 2.65J)
Prereq.: Permission of Instructor
G (2)
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 emulsion phase in dense bubbling 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 exchangers and fluidized-bed combustors.
A. F. Sarofim, 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 of 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

10.66 Polymer Rheology Laboratory (A)

Prereq.: 10.301
G (2) **Next offered 1987-88**
1-5-6

Experimental methods for characterizing polymeric fluids. Shear flow properties including non-Newtonian viscosity, normal stress differences, linear viscoelastic properties, and transient nonlinear properties. Elongational flow properties. Effects of concentration, molecular weight distribution, molecular structure. Theory for analysis of experimental results. Permission of instructor required.
R. C. Armstrong, R. E. Cohen

10.67 Polymer Science Laboratory (A) (Revised Content)

Prereq.: Permission of Instructor
G (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.
R. E. Cohen, U. W. Suter

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 to extensional flows.
E. W. Merrill

10.682J Statistics of Macromolecular Systems (Revised Content)

(Same subject as 5.65J)
Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-6

Structure, configuration and conformation of macromolecules. Polymerization and copolymerization statistics. Spatial arrangement of chains, linear and non-linear, 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, U. W. Suter

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, etc. Process conditions: bulk, solution, emulsion, suspension, gas phase, batch vs continuous fluidized bed, etc. "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 propagation in premixed gas mixtures, laminar burner flames, turbulent flames, enclosed and swirling jet flames, flame stabilization, heterogeneous combustion of fuel droplets and particles. Diffusional and chemical kinetics, pollutant formation and destruction in flames. Coal combustion systems: stoker, pulverized coal, fluidized combustion of coal.
J. M. Beér

10.731 Seminar in Combustion Chemistry

Prereq.: Permission of Instructor
G (1, 2)
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, J. P. Longwell

10.732 Gas-Solid Reactions

Prereq.: Permission of Instructor
G (1, 2)
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.
J. P. Longwell, A. F. Sarofim

10.74J Radiative Transfer (A)

(Same subject as 2.58J)
Prereq.: 10.302 or 2.51
G (2) **Next Offered 1987-88**
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) **Next offered 1987-88**
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.
D. G. Jansson

10.805 Technology, Law, and the Working Environment

Prereq.: Permission of Instructor
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, L. B. Evans

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)
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 of their Noryl Plastics Division at Selkirk, NY, and Silicone Products Division at 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 section on School of Chemical Engineering Practice for details. Enrollment limited and subject to plant availability.
J. W. Tester

10.84 (10.85, 10.86, 10.87) School of Chemical Engineering Practice -- Industrial Station (A)

Prereq.: Permisssion 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 section on School of Chemical Engineering Practice for details. Enrollment limited and subject to plant availability.
J. W. Tester

10.88 (10.89) School of Chemical Engineering Practice — Brookhaven Station (A)

Prereq.: Permission of Instructor
G (S)
0-12-0

Conducted at Brookhaven National Laboratory, Upton, NY. Group problem assignments emphasizing application of chemical engineering to synthetic hydrocarbon fuels and alternate energy resources, electrochemistry, environmental science, and nuclear technology. Credit granted in lieu of a Master's thesis; see section on School of Chemical Engineering Practice for details. Enrollment limited and subject to plant 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.
W. M. Deen

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.
C. M. Mohr

10.94 Special Problems in Chemical Engineering

Prereq.: Permission of Instructor
U (1, 2)
Arr.

Problem of current interest, varying from year to year.
J. P. Longwell

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.
W. M. Deen

10.971 Seminar in Fluid Mechanics and Transport Phenomena

Prereq.: Permission of Instructor
G (1, 2)
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

10.972 Biochemical Engineering Research Seminar

Prereq.: Permission of Instructor
G (1, 2)
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)
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, M. L. Yarmush

10.974 Catalysis and Reaction Engineering

Prereq.: Permission of Instructor
G (1, 2)
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 those areas, but open to students with background and interest in related areas such as surface sciences and non-catalytic reactions.
J. Wei, C. N. Satterfield

10.975 Seminar in Polymer Science and Engineering (A)

Prereq.: Permission of Instructor
G (1, 2)
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, U. W. Suter

10.976 Process Synthesis and Control

Prereq.: Permission of Instructor
G (1, 2)
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 (New)

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

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.
Geo. Stephanopoulos

10.978 Applied Thermodyanmics and Applied Heat and Mass Transport

Prereq.: Permission of Instructor
G (1, 2)
2-0-4

Review of current topics in applied and theoretical thermodynamics and transport. Subjects include 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 biological and geological systems.
J. W. Tester, T. A. Hatton

10.979 Plasma Processing

Prereq.: Permission of Instructor
G (1, 2)
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)
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

10.991 Seminar in Chemical Engineering (A)

Prereq.: Permission of Instructor
G (1)
2-0-4

10.992 Seminar in Chemical Engineering (A)

Prereq.: Permission of Instructor
G (2)
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.
W. M. Deen

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 which 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 1987-88**
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)
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) HUM-D
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 (1) 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) HUM-D
3-0-9

See description under subject 17.201J.
G. T. Marx, M. Lipsky, M. W. Weinberg

11.008J Urban Economics

(Same subject as 14.51J)
Prereq.: 14.01
U (1) HASS
3-0-6

See description under subject 14.51J.
J. Rothenberg, 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

11.015J Structuring Computer Programs for Architecture and Planning (New)

(Same subject as 4.201J)
Prereq.:—
U (1)
4-4-4

Taught in step with 6.001, with students attending 6.001 lectures and doing problem sets. Separate recitations and tutorials concentrating on applications to architecture and planning. Students do individual projects in areas of their interest. Same subject as 11.215.
A. Fleisher

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

11.122 Environmental Policy and Regulation

Prereq.: —
U (1) HASS
3-0-9

See description under subject 11.361.
M. G. Klapp

11.131 The Urban Neighborhood

Prereq.: —
U (2) HUM-D
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) HUM-D
3-0-9

Introduces law, organized around the theme of how the law shapes, influences, and constrains the design and implementation of policy. Examines relationship between courts and line agencies. Analyzes how courts differ from other policy-making institutions. Includes basic legal research.
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)
Arr.

Undergraduate research opportunities in Urban Studies and Planning. For further information consult the Departmental Coordinator.
P. L. Clay

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)
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)
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 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. Taught in conjunction with 11.210 and 11.220. Restricted to first year M.C.P. students.
P. L. Clay, D. A. Schon

11.205 Planning Roles and Institutions in Developing Countries

Prereq.: —
G (1)
3-0-9

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.
R. A. Gakenheimer, B. Sanyal

11.206 Core Practicum

Prereq.: —
G (1)
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. Taught in conjunction with 11.200, 11.210, and 11.220. Restricted to first-year M.C.P. students.
P. L. Clay

11.210 Political Economy for Planners

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 and aggregate 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

11.215J Structuring Computer Programs for Architecture and Planning (New)

(Same subject as 4.201J)
Prereq.:—
U (1)
4-4-4

See description under subject 11.015J.
A. Fleisher

11.216 Writing for Public Policy and Planning

Prereq.: —
G (2)
2-1-1

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

11.217 Bargaining and Negotiation

Prereq.: —
G (1)
2-1-1

Introduces methods and formal theory of bargaining and negotiation. Analyzes ways in which procedure, structure of bargaining situation, preferences of negotiators, and tactics of bargainers can lead to the success or failure of negotiations. Uses case study and gaming materials in class. Permission of instructor required.
L. E. Susskind

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 sector and private sector financial issues.
L. B. Sagalyn

11.219 Library Research Methods

Prereq.: —
G (1)
2-1-1

Teaches planning students skills needed to access library information while in school, and later as practicing professionals. Problem-oriented; learn by doing. Class time spent discussing and practicing appropriate methodologies for researching specific topics of interest. Examples of resources covered: periodical indices, government documents, the US Census, computerized literature searching, and the union catalogue.
M. E. Depopolo

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. Taught in conjunction with 11.200 and 11.210. 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.
G. Hack

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 (Revised Unit)

Prereq.: 11.220
G (1)
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., R. C. Larson

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 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

11.231 Social Research Methods

Prereq.: —
G (2)
3-6-3

Introduces methods and process of social research. Explores various methods — surveys, case studies, comparative research, social area analysis — in the context of specific research topics. Emphasizes development of research designs, selection of appropriate methods, and use of primary and secondary data. Hands-on experience in interviewing and survey research. Same subject as 11.188.
P. L. Clay, J. Ferreira, Jr.

11.233 Comparison and Lesson Drawing

Prereq.: —
G (1) **Next offered 1987-88**
2-0-7

Focuses on issues in comparative policy analysis in housing and other areas by comparing experience 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

11.234 Laboratory in Data Analysis for Planners (A)

Prereq.: 11.220 or 18.057
G (2)
3-6-3

Hands-on experience analyzing social science data of interest to planners using statistical computer packages. The methodological focus is on hierarchical models: regression and analysis of variance for metric data; and logit, ordit, and loglinear models for categorical data. Requirements include five short data analyses and a term paper.
A. Fleisher

11.235 Analyzing Projects and Organizations (Revised Unit)

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 (New)

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

11.311J Environmental Programming Workshop (A) (Revised Unit)

(Same subject as 4.745J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 4.745J.
S. C. Howell

11.312J Facility Programming and Management (A)

(Same subject as 4.742J)
Prereq.: —
G (2)
3-0-6

Techniques for programming buildings and other settings to fulfill societal and private goals. Considers the nature and type of information required by clients before committing resources for design and construction: locations, quantities of space and fixtures, longevity required, flexibility, arrangements for management and maintenance. Systems for facility planning and of capital investments over time. Lectures, discussions, and projects.
T. F. Lee

11.320 History of Urban Development

Prereq.: —
G (2)
3-0-6

Lectures and readings on urban America from rough [illegible] 1890 to the present. Focuses on the city as an arena in which social classes and ethnic groups struggle over distribution of wealth, power, and prestige. Topics may include: emergence of political machines; transformation of police, schools, and courts; changes in real estate development, regulation of land use; construction of roads, sewers, and rail transit; reforms in municipal finance; and changes in city-state and city-Federal relations.
R. M. Fogelson

11.328J Community, Class and Race: A Social Perspective (A)

(Same subject as 4.766J)
Prereq.: —
G (2)
3-0-6

See description under subject 4.766J.
E. Robbins

11.330J Theory of City Form (A) (Revised Unit)

(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) (Revised Content)

Prereq.: Premission of Instructor
G (2)
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 (1)
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 (2)
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.
G. Hack

11.337J Implementation Strategies for Urban Design

(Same subject as 4.746J)
Prereq.: Permission of Instructor
G (1)
Arr.

Focuses on the means, methods, and tools for achieving urban design objectives and complementary projects. Reviews classic and contemporary problems faced by the profession and strategies utilized to resolve them, such as: new town development, downtown revitalization, neighborhood preservation, and transportation development. Includes: public finance and development, zoning and land-use control, development incentives, innovative public and private partnerships.
J. de Monchaux

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

11.339 Environmental Design Policy (A) (New)

Prereq.: 11.301J
G (1)
3-0-6

Seminar focusing on the ways that governments have attempted to influence the quality of environmental design. Considers various policy mechanisms including: incentives, standards and regulations, compensation, negotiation, and information based strategies. Conditions under which each mechanism is likely to succeed or fail are studied. Students complete a research paper on a topic of their own choosing.
J. M. D. Schuster

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 (Revised Unit)

Prereq.: 11.210 or 14.01
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) (Revised Content)

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

11.364 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.
M. Wheeler

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.: Permission of Instructor
G (2)
4-0-8

Analysis of development in a political context. Includes: interest group politics, the politics of public approvals, impact of development on neighboring groups, public-private partnerships, and training in negotiating skills.
B. J. Frieden, 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 (2)
3-0-6

See description under subject 1.252J.
R. A. Gakenheimer

Community and Regional Development

11.400 Community Development (New)

Prereq.: Permission of Instructor
G (1)
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) (Revised Content)

(Same subject as 14.573J, 1.283J)
Prereq.:—
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.
W. C. Wheaton, J. Rothenberg

11.411J Fiscal Federation and Local Public Sector (A)

(Same subject as 14.574J)
Prereq.:—
G (2) **Next offered 1987-88**
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 (1)
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) (Revised Content and Unit)

(Same subject as 4.743J)
Prereq.: 11.200 or 4.144
G (2) **Not to be offered 1987-88**
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 (New)

(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) (Revised Content and Unit)

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
G (2)
3-0-9

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.
P. David

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 (1)
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)

Prereq.: —
G (2)
2-0-6

Focuses on recent downtown development projects involving joint participation by local governments and private developers. Analyzes ways both sectors work together, plan, finance, and implement specific projects. Examines context for these efforts: urban renewal, changing functions of downtowns, Federal and local policies effecting central cities. Uses detailed case studies of several downtown shopping developments.
B. J. Frieden

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) (New)

Prereq.: 11.400
G (2)
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 Practicum in Community Development (New)

Prereq.: Permission of Instructor
G (2)
Arr.

Workshop dealing with neighborhood, housing, and community development issues.
L. C. Keys

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

11.453 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 which may include pre-thesis work.
B. J. Frieden, P. L. Clay

11.454 Innovations in Housing and Community Development (A)

Prereq.: —
G (1)
2-0-7

Design and implementation of innovative proposals for housing and community development. Considers policy as well as projects, focusing on the role of the state vis-à-vis Federal and local governments and the private sector. Guest lecturers discuss current issues in Massachusetts state government.
L. C. Keyes

11.456 Research Seminar in Community and Regional Development (A) (New)

Prereq.: Permission of Instructor
G (1)
2-0-7

For second-year MCP 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.
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.
L. Rodwin

11.462 Housing Problems, Goals, and Policies in Developing Countries (New)

Prereq.: —
G (1)
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.
L. Rodwin

11.463J Local Housing Policies in Developing Countries

(Same subject as 4.753J)
Prereq.: —
G (2)
3-0-6

Examines housing needs of income groups in cities of different sizes and analyzes policy options for development of housing programs. Emphasis on aspects vital to the design and implementation of projects: affordability, land acquisition, cost-recovery, political support, institutional arrangements, and maintenance. Mechanisms for monitoring and evaluation of projects.
B. Sanyal, 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 sectors contribution to development. The role of women and the possibilities of non-monetary activities explored.
B. Sanyal

11.468 The Implementation of Metropolitan Planning in Developing Countries

Prereq.: Permission of Instructor
G (2)
3-0-9

Emphasizes techniques for management and guidance of housing programs and land occupancy and their effects on development and equity in developing countries. Roles of urban planning in developing countries. Analyzes cases of planning and decision making, the study of "terms of relevance" for planning services, and the programming of urban infrastructure. Conducted jointly with Harvard Graduate School of Design.
R. A. Gakenheimer

11.469J Infrastructure in Third-World Countries (A) (New)

(Same subject as 1.254J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Planning for transport, water supply sewerage, and electric power. Covers political, economic, institutional and distributional considerations of infrastructure decisions and outcomes. Relates infrastructure developments to themes in third-world development and planning: 1) growth sequence and linkages, 2) building viable public-sector institutions, 3) planning and financing of development, 4) equity questions, 5) technocratic decision making, and 6) role of political and economic groups.
R. A. Gakenheimer, J. Tendler

11.470 Political Economy of Development Projects

Prereq.: —
G (1)
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 (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 (2)
3-0-9

Covers impacts of various types of projects on income distribution; difficulties of assuring that project benefits reach the poor; types of project, 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 non-economic) 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) **Next offered 1987-88**
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 non-agricultural 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 (New)

(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. Taylor

11.487 Energy Sector Planning in Developing Countries (New)

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

Public Policy and Management

11.500 Introduction to Public Policy and Management

Prereq.: —
G (1)
3-1-8

Introduces the theory and practice of public policy formulation and implementation. Emphasizes applications and limitations of public policy analysis. Examines theories of public policy implementation for their implications for effective management in the public sector. Same subject as 11.002.
R. C. Larson

11.505 Seminar on Nonprofit Institutions and the City (A)

Prereq.: 11.200 or 11.230
G (2) **Next offered 1987-88**
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) **Next offered 1987-88**
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) **Next offered 1987-88**
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 underlies 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

11.517 Public Finance in Developing Countries (A)

Prereq.: 11.210
G (1)
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

11.540 Practicum on Public Management and Policy I

Prereq.: Permission of Instructor
G (1)
Arr.

11.541 Practicum on Public Management and Policy II

Prereq.: 11.540
G (2)
Arr.

Workshop dealing with public management issues in a specific public organization. Consult: R. C. Larson

11.550 Conflict, Dispute Resolution, and Negotiation 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, focuses 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

Doctoral Seminars

11.800 Doctoral Seminar I (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

11.801 Doctoral Seminar II (A)

Prereq.: Permission of Instructor
G (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)
Arr.

11.912 Reading Seminar in Urban Studies and Planning (A)

Prereq.: Permission of Instructor
G (2)
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)
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.
T. Lee

11.962 Urban Fieldwork and Internships (A)

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Practical application of planning techniques to towns, cities, and regions, including problems of replanning, redevelopment, and renewal of existing communities. Includes internships in municipal and state agencies and departments under staff supervision.
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

12 Earth, Atmospheric, and Planetary Sciences

Undergraduate Subjects

12.UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in Earth, Atmospheric, and Planetary Sciences. Consult W. F. Brace

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 Geological Processes, Features, and History

Prereq.: —
U (1) SD
3-4-5

Introductory course in geology. 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 and geologic mapping techniques. Two non-required weekend days of field trips.
J. B. Southard

12.011 Sedimentary Processes: Rivers

Prereq.: 12.01
U (1) **Next offered 1987-88**
1-0-3

Nature of streamflow; modes of fluvial sediment transport; development of meandering and braided channel patterns; sedimentary structures and sedimentary sequences developed in fluvial deposits; recognition and interpretation of ancient fluvial sequences.
J. B. Southard

12.012 Sedimentary Processes: Glaciers

Prereq.: 12.01
U (2) **Not to be offered 1987-88**
1-0-3

Development and flow of valley glaciers and continental ice sheets; erosion and transportation of sedimentary material by glaciers; modes and forms of accumulation of glacial deposits; Pleistocene glacial history of North America; record of glaciations through geologic time.
J. B. Southard

12.013 Sedimentary Processes: The Wind

Prereq.: 12.01
U (1) **Not to be offered 1987-88**
1-0-3

Dynamics of wind erosion and transportation; form, migration, and stratification of sand dunes; loess; wind-borne sediment supplied to the oceans; recognition of eolian deposits in the geological record.
J. B. Southard

12.014 Sedimentary Processes: Coastlines

Prereq.: 12.01
U (2) **Next offered 1987-88**
1-0-3

Waves and currents in the shallow ocean; movement of sand on beaches; form and stratification of beach deposits; estuaries and estuarine sedimentation; sediment distribution and transportation on modern continental shelves; nearshore sediments in the geological record.
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 modern 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

12.02 Chemistry and Physics of Minerals and Rocks

Prereq.: —
U (2) 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

12.043J Introduction to Mining and Mineral Technology

(Same subject as 1.384J, 3.095J)
Prereq.: —
U (1)
3-0-6

See description under subject 3.095J.
J. F. Elliott, R. G. Burns, H. H. Einstein, C. R. Peterson

12.051 Field Geology I

Prereq.: 12.02, *12.03*
U (1) **Next offered 1987-88**
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 1987-88**
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)
3-6-3

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. One day field trip.
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.
Staff

12.095 Teaching Earth and Planetary Sciences

Prereq.: Permission of Instructor
U (1, 2)
Arr.

For undergraduate students with appropriate course experience to assist in laboratory and classroom teaching, or in the composition and grading of outside assignments, under faculty supervision. Available positions listed in department headquarters well before the start of each semester. Students selected by interview. Pass/fail subject. Consult Department headquarters.

12.105 Introduction to Field Geophysics

Prereq.: 18.03
U (1) **Not to be offered 1987-88**
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 1987-88**
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, earth tides), 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 (New)

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, Staff

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.
D. C. Jewitt, 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, L. M. French

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 on 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.
L. M. French, J. L. Elliot

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, C. C. Counselman

12.132J Planetary Science II

(Same subject as 8.292J)
Prereq.: 12.131J or 8.291J
U (2) SD
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, J. Wisdom

12.133J Dynamical Astronomy

(12.115)
(Same subject as 8.293J)
Prereq. 18.03, 8.03, 12.131
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.
C. C. Counselman

12.151 Advanced Field Geology I (A) (New)

Prereq.: 12.02, 12.03, 12.051, 12.052
G (1) **Not to be offered 1987-88**
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) (New)

Prereq.: 12.151
G (J, 2) **Not to be offered 1987-88**
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 (Revised Content and Unit)

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)
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

12.24 Topics in the Physics of Atmospheres and Oceans

Prereq.: 8.03, 18.03
U (1)
3-0-9

Representative problems in meteorology and physical oceanography selected to illustrate the scientific methods and principles used in these fields. Includes: the evolving view of extratropical cyclones, the general circulation of the oceans, tides, predictability, atmospheric electricity, and the impact of changes in solar constant on climate. Primarily for juniors and seniors.
P. H. Stone, Staff

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 W. F. Brace.

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)
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)
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 1987-88**
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)
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) (New)

Prereq.: 12.03
G (1) **Not to be offered 1987-88**
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)
2-0-4

Discussion of current research or advanced topics in continental tectonics, rock mechanics, or experimental structural geology.
W. F. Brace, B. Evans

12.36 Sedimentary Basins (A) (New)

Prereq.: 18.03, 12.03
G (2) **Not to be offered 1987-88**
3-0-6

Formation and evolution of basin systems in continental crust (including passive continental margins, foredeep accretionary basins, backarc 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

12.385-12.399 Special Problems in Geology-Geochemistry (A)

Prereq.: —
G (1, 2)
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); *S. R. Hart* (12.393); *Staff* (12.394); *B. C. Burchfiel* (12.395); *J. B. Southard* (12.396); *E. A. Boyle* (12.397); *Staff* (12.398, 12.399).

12.401 Meteorites: From Stones to Stars

Prereq.: 12.02
U (2)
2-0-2

Discusses various classification schemes for meteorites based on metamorphic, chemical, and isotopic criteria; early chronology of the solar system and cosmochronology based on long- and short-lived isotopes; chemical composition of meteorites and its relationship to other solar system objects; condensation theory; nucleosynthesis and the isotopic composition of meteorites; the origin of cosmic rays and solar wind and their record in meteorites; ancient sun activity and ancient galactic evolution. Subject offered last half of semester. Consult C. J. Allegre, S. R. Hart.

12.402 Isotopic Tracers in Metallogenesis

Prereq.: 12.02
U (2)
2-0-2

Discusses principles of stable isotope fractionation; systematics of the stable isotopes of hydrogen, carbon, oxygen, and sulfur in ore deposits; principles of radiogenic isotopes as geologic tracers and the systematics of Sr, Nd, Pb, and rare-gas isotopes in ore deposits; case studies of the use of both stable and radiogenic isotopes in ore deposit genesis; regional aspects of ore deposits and their relationship to the chemical geodynamics model. Subject offered last half of semester. Consult C. J. Allegre, S. R. Hart.

12.411 Isotope Geology (A)

Prereq.: 12.02
G (2) **Not to be offered 1987-88**
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 (1) **Next offered 1987-88**
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 Mossbauer, 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) (New)

Prereq.: 3.01 or 5.60, 12.062, 18.03
G (1) **Next offered 1987-88**
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.: 12.071
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 1987-88**
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 1987-88**
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)
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-hour tutorial each week.
M. K. McNutt, T. H. Jordan

12.502 Plate Tectonics and Marine Geophysics (A)

Prereq.: 8.03, 18.075
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. Seismological constraints on plate structure. Applies these ideas to the evolution of the ocean basins.
M. K. McNutt

12.512 Geoelectricity (A)

Prereq.: 8.03, 18.076
G (2) **Next offered 1987-88**
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
G (2) **Not to be offered 1987-88**
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 Seismic Imaging (A)

Prereq.: 12.107 or 12.521; 6.003 or 6.341 or 12.761 or 13.74J
G (2) **Not to be offered 1987-88**
3-0-6

The use of seismic techniques to image the subsurface. Emphasis placed on wave propagation modeling and signal processing for reflection and vertical seismic profiling. Includes statics, stacking, deconvolution, wavelet estimation, velocity estimation, f-k filtering, tau-p analysis, migration, tomographic methods, modeling, inversion, seismic sources and stratigraphic interpretation.
G. L. Duckworth

12.521 Elements of Seismology (A)

Prereq.: 18.075
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 1987-88**
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)
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, S. C. Solomon, M. N. Toksöz

12.524 High-Frequency Seismology (A)

Prereq.: 8.06, 18.076
G (2) **Next offered 1987-88**
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

12.53 Inverse Problems in Geophysics (A)

Prereq.: 18.075
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) **Next offered 1987-88**
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.
G. L. Duckworth, A. B. Baggeroer

12.54 Planetary Interiors (A)

Prereq.: 12.07, 18.075
G (2) **Not to be offered 1987-88**
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

12.56 Advanced Seminar in Plate Tectonics (A)

Prereq.: 12.07, 12.502
G (2)
3-0-6

Basic observations and theoretical developments in sea-floor spreading, plate tectonics, continental tectonics, and marine geophysics. Data from seismic, magnetic, heat flow, gravity measurements and other sources used to study the properties of the lithosphere, the asthenosphere, and the motions of the plates. Reviews key papers and latest articles.
T. M. Jordan, M. K. McNutt, L. H. Royden, S. C. Solomon, M. N. Toksöz

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
G (2) **Not to be offered 1987-88**
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)
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); *Staff*,(12.587); *S. C. Solomon* (12.588); *Staff* (12.589), *T. H. Jordan* (12.590); *G. L. Duckworth* (12.591); *Staff* (12.592, 12.593, 12.594)

12.600-12.614 Special Problems in Geophysics (A)

Prereq.: —
G (1, 2)
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); *Staff* (12.607); *W. F. Brace* (12.608); *Staff* (12.609); *T. H. Jordan* (12.610); G. L. Duckworth (12.611); *Staff* (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)
Prereq.: 8.03, 18.075
G (1) **Next offered 1987-88**
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. Radiowave scattering. Uses of interferometry in radar mapping astrometry and geodesy.
G. H. Pettengill, C. C. Counselman, D. H. Staelin

12.660 Planetary Rings (A)

Prereq.: 12.131J or 8.291J, 18.075
G (2) **Next offered 1987-88**
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

12.690 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)
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); *Staff* (12.698, 12.699).

Meteorology and Oceanography

12.701 Marine Sediments (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
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 paleo-oceanographic studies.
(Woods Hole Staff): W. Curry

12.702 Oceanic Volcanology and Petrology (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
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) **Next offered 1987-88**
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) (New)

Prereq.: General and Historical Geology
G (2) **Next offered 1987-88**
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 nannannofossils, 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 1987-88**
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 (2)
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)
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)
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)
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 1987-88**
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 DSDP materials 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 1987-88**
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 versus 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)
(Revised Content and Unit)

Prereq.: Permission of Instructor
G (1)
2-0-10

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, P. Brewer

12.743 Geochemistry of Marine Sediments (A)

Prereq.: 5.11 or 3.091, 5.60
G (1) **Not to be offered 1987-88**
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)
(New)

Prereq.: 12.742 or 12.741
G (2) **Not to be offered 1987-88**
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

12.745 Ore Deposition at Submarine Ridge Axes (A)
(New)

Prereq.: —
G (1) **Not to be offered 1987-88**
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 1987-88**
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

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.
(Woods Hole Staff)

12.761 Oceanographic Time Series (A)

Prereq.: 18.075
G (1) **Next offered 1987-88**
3-0-6

Examines aspects of the problems encountered in using real, finite, discrete time series data from oceanographic experiments. Includes z-transforms, Wiener filters, minimum phase systems, spectra, bi-spectra, array antennas, data adaptive methods.
C. Wunsch

12.762 Experimental Physical Oceanography (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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) **Not to be offered 1987-88**
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)
(Revised Unit)

Prereq.: Permission of Instructor
G (2)
1-3-3

A substantial portion devoted to simple experiments which simulate large-scale geophysical flows and hence involving 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 1987-88**
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 1987-88**
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 1987-88**
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 which 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.
(Woods Hole Staff): N. Hogg

12.791 Topics in Modern Observational Physical Oceanography (A)

Prereq.: 18.075
G (1) **Not to be offered 1987-88**
3-0-6

Topics in large-scale observational/theoretical oceanography not included in more conventional courses. The theme is the problem of observing the ocean on basin and global scales through recent developments in observational techniques and their associated mathematical methods. Introduces acoustic tomography, satellite altimetry, large-scale general circulation and chemical tracers, inverse methods, linear and quadratic programming, objective mapping, optimal estimation theory.
C. Wunsch

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.
E. N. Lorenz

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 which apply to either fluid and contrasts between them. Including 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.
W. R. Young

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.
C. Wunsch

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 non-rotating and rotating fluids: specifically internal gravity waves, tides, Rossby waves, barotropic and baroclinic instabilities. The interaction of these asymmetric components of the motion of the atmosphere 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.
P. H. Stone, 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.: 8.03, 18.03
U (1)
3-3-6

12.812 Introduction to Meteorology (A)

Prereq.: 8.03, 18.03
G (1)
3-3-6

Development of elementary dynamical concepts such as geostrophic and hydrostatic balance, conservation of momentum and energy, and circulation and vorticity conservation. Atmospheric thermodynamics. Kinematics of atmospheric flows. Exposition and basic physics of atmospheric phenomena, including the general circulation, extratropical cyclones and anticyclones, tropical storms, stationary waves, and cumulus convection. Laboratory studies illustrating fundamentals of meteorological data analysis and forecasting. Serves as a general introductory course open to juniors and seniors and encouraged for graduate students with no prior exposure to meteorology.
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 extra-tropical cyclones and anticyclones from polar-front theory to quasigeostrophic 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
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. Remote 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 1987-88**
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.: 1.612 or 2.20 or *16.035*
G (1)
3-0-9

See description under subject 16.044J.
M. T Landahl, J. H. Haritonidis

12.866 Atmospheric Convection (A)

Prereq.: 12.800
G (2) **Not to be offered 1987-88**
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

12.873 Upper Atmosphere and Ionosphere (A)

Prereq.: 12.800, 12.850
G (2) **Not to be offered 1987-88**
3-0-9

Describes composition, structure, circulation, and energetics of upper atmosphere and ionosphere. Transport of trace substances and atmospheric escape. Chemical kinetics in atmosphere. Photochemical-dynamical steady states. Dynamics of upper atmosphere. Excitation and propagation of internal gravity and quasi-geostrophic waves. Describes stratospheric ozone layer, emphasizing interactions between chemistry, dynamics, and radiation. Physics and dynamics of ionosphere and magnetosphere and coupling to the neutral atmosphere.
R. G. Prinn, J. C. Foster, J. M. Holt, W. L. Oliver

12.874 Cloud and Precipitation Physics (A)

Prereq.: 12.850, 18.03, 5.60
G (1)
3-0-9

Introduces physics and chemistry of hydrometeor nucleation and growth in convective and stratiform cloud systems, with discussions of the physics and state-of-the-art of cloud seeding. Consult Center headquarters, 54-1712.

12.875 Radar Meteorology (A)

Prereq.: 12.874
G (2)
3-0-9

Introduces radar sensing of the atmosphere emphasizing the meteorological information content of coherent (Doppler) and non-coherent (non-Doppler) radar signals. Consult Center headquarters, 54-1712

12.876 Measurements in the Atmosphere (A) (New)

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.
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.
Staff (12.960); *G. R. Flierl* (12.961); *P. Malanotte-Rizzoli* (12.962); *C. I. Wunsch* (12.963); *W. R. Young,* (12.964); *Staff* (12.965-12.969).

12.975J Principles and Physics of Remote Sensing (A)
(New)

(Same subject as 1.695J)
Prereq.:—
G (1) **Not to be offered 1987-88**
3-0-6

Properties of microwave scattering, infrared radiation, thermal emission from rough surfaces, and interference by the atmosphere. Optical theory for visible and near-infrared wavelengths. Celestial mechanics for understanding orbital dynamics and geometric distortions. Review of modern satellite-borne sensors and related technology and data analysis. Emphasis on new methodologies and data interpretation. Examples are derived to cover a wide range of oceanographic, atmospheric, and geophysical phenomena. Permission of Instructor.
(Woods Hole Staff): H. C. Graber, J. S. Jaffe, K. A. Kelly

12.976J Application of Remote Sensing and Image Processing (A)
(New)

(Same subject as 1.696J)
Prereq.:—
G (2) **Not to be offered 1987-88**
3-3-3

Remote sensing techniques learned in 12.975J will be applied to real data from SEASAT, GOES, NIMBUS, etc. Students will choose a data set and perform their own processing on an image processor. They can be used to test concepts in visible, infrared, active, and passive microwave scattering methods. Lectures will cover principles of image processing, smoothing, filtering, noise reduction, and sensor calibration errors. A knowledge of computers and programming techniques is assumed. Permission of Instructor.
(Woods Hole Staff): H. C. Graber, J. S. Jaffe 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); *E. N. Lorenz* (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)
Arr.

Organized lecture or laboratory subject on some aspect of meteorology not normally covered in the regularly scheduled subjects.
Staff

13 Ocean Engineering

13.UR Undergraduate Research

Prereq.: —
U (1, 2, S)
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)
3-6-3

Elementary principles of naval ship design and statics of naval architecture. Fairing of naval ship lines, calculations for and drawing of displacement and other curves, cross curves of stability, curves of statical stability, and floodable length curves. Basic concepts from strength of materials and idealization of a ship as a beam. Froude scaling and ship resistance calculations. Basic rigid body dynamics and introduction to ship motions due to wave excitation.
W. D. Whiddon

13.021 Marine Hydrodynamics I

Prereq.: 1.05 or 2.20
U (1)
4-1-7

Develops hydrodynamic principles and their application 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. 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

13.05 Applied Hydrodynamics of Ship Design (A) (New)

Prereq.: 13.021
G (1)
4-0-8

Application of developments in theoretical, experimental, and analytical hydrodynamics to ship design (and operation) in certain areas of resistance, propulsion, maneuvering, and seakeeping. Relevant material on free surface, boundary layer, and circulation hydrodynamics, and their application in the design process. Mathematical and physical modeling approaches to evaluate the necessary quantitative information including conducting of scaled model tests in the MIT Towing Tank.
M. A. Abkowitz

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 involving 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 1987-88**
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 assumed, equivalent to that covered in 13.022. Alternates with 13.09.
J. N. Newman

13.08 Stability and Motion Control of Ocean Vehicles (A)

Prereq.: 13.021, 18.075
G (2) **Not to be offered 1987-88**
4-0-8

Motion equations in six degrees of freedom, mathematical simulation models for ocean vehicle motions, and effects of excitations from control systems and ocean environment on motion response. Solutions for stability and important motions and comparisons between simulation model results and physical reality. Applications to typical ocean vehicles such as ships, submarines, hydrofoils, platforms, buoys, and towed systems.
M. A. Abkowitz

13.09 Potential Flows (A)

Prereq.: 13.022; 18.076 or 18.304
G (1) **Not to be offered 1987-88**
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 (Revised Content and Unit)

(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, D. G. Karr, J. H. Williams, Jr.

13.111 Structural Mechanics (A)

Prereq.: 13.10J
G (1)
3-0-9

Concept of strain and equilibrium in continuum mechanics, plates, and shell structures. Theory of linear elasticity. Application of the calculus of variation and energy methods in structural mechanics. 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

13.112J Analysis and Design of Offshore Structures (A)

(Same subject as 1.551J)
Prereq.: 1.51 or 13.10J
G (1)
4-0-8

See description under subject 1.551J.
J. K. Vandiver, S. Shyam Sunder

13.121 Ship Structures (A)

Prereq.: 13.111
G (2)
3-0-6

Ship longitudinal strength and hull primary stresses. 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 open and closed sections with free and restrained warping. Effective breadth and width. Grillages, ship plates, and the effect of stiffeners. Ship transverse strength. Hull dynamics. Statistical approach to strength.
A. Moshaiov

13.122 Ship Structural Design (A)

Prereq.: 13.10J
G (S)
3-0-6

Ship structural design concepts. Role of the Classification Societies in structural design process. Design loads. Design of common naval architecture structural elements, like girders, stanchions, plates, and grillages. Plastic design methods and structural optimization. Design of joints and connections and typical structural details. Cost and management considerations in structural design process. Several projects carried out during term.
W. D. Whiddon

13.123 Advanced Analysis and Design of Ocean Engineering Structures (A)

Prereq.: 13.111 or 13.112J
G (2) **Not to be offered 1987-88**
3-0-6

Ocean engineering structural configurations: fixed-base platforms, semi-submersibles, cable and moorings, pipelines, marine risers. Environmental loads. Introduces materials for ocean engineering. Fixed-base platforms. 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.
D. G. Karr

13.124 Response of Marine Structures to Impulsive Loading (A)

Prereq.: 13.111
G (2) **Not to be offered 1987-88**
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)
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 1987-88**
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.
A. S. Argon, O. Buyukozturk

13.15 Materials for Ocean Engineering

Prereq.: —
G (2)
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.: 1.02J 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 1987-88**
2-0-4

Problems occur in various welded structures, including ships, offshore oil drilling rigs, pressure vessels, bridges, and aerospace structures. Discusses problems: 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) **Not to be offered 1987-88**
2-0-4

Analyzes problems related to fabrication of structures, such as ships, aircrafts, rockets, pressure vessels, buildings, and ocean engineering structures by various joining processes including welding, riveting, and adhesive bonding. Discusses such problem areas as fracture characteristics of welded structures; residual stress, distortion, and stress relieving; advanced welding metallurgy; non-destructive 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

13.41 Ocean Engineering Design Principles (A)

Prereq.: 13.40, *13.021*
G (1)
3-3-6

Loads and motions of ships and offshore structures caused by waves, winds and current; Morison's equation; inertia-dominated flows; impact loads; wave drift forces in regular and irregular seas. Short term and long term statistics, wave spectra and wind spectra, the one hundred year wave. Mooring statics and dynamics; dynamic positioning. Emphasizes appropriate selection of coefficients and parameters involved, and design considerations that lead to safe and economic systems.
M. S. Triantafyllou, C. Chryssostomidis

13.411 Principles of Naval Ship Design (A)

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.
C. Graham, W. D. Whiddon

13.412 Principles of Ship Design (A)

Prereq.: 13.021; 13.10J or 13.111 or 13.122; 13.41
G (2) **Not to be offered 1987-88**
2-4-6

Ship in context of a larger system; formal optimization procedures applied to ship design; assumption of subsystems sufficiency; mathematical model of ship design process; engineering and economic principles governing selection of dimensions and coefficients of ships and submarines; design of hull form; principles governing internal subdivision for maximum survivability; influence of hull form and dimension selection on operability in rough seas. Design exercise in application of principles. Not recommended for students who have taken 13.441.
C. Chryssostomidis, M. S. Triantafyllou

13.431 Methods of Naval Ship-System Design (A)

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.
C. Graham

13.441 Offshore Engineering Design (A)

Prereq.: 13.10J, 13.40
G (2) **Next offered 1987-88**
2-4-6

Methodology for offshore system design. Definitions of design problem emphasizing problem objectives, design criteria, and modeling techniques. Assesses probability of failure using environmental data, short- and long-term statistics; extreme loads; fatigue. Presents a complete example for a semisubmersible or a tension leg platform and requires a term project.
M. S. Triantafyllou

13.451 Projects in Naval Ships Conversion Design (A)

Prereq.: 13.411 or 13.412; 13.431; 13.21
G (2)
Arr.

Project studies focused 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.
C. Graham, W. D. Whiddon

13.461 Projects in New Construction Naval Ship Design (A)

Prereq.: 13.411 or 13.412; 13.431; 13.122; 13.21
G (1, 2, S)
Arr.

Project studies focused 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.
C. Graham, W. D. Whiddon

13.462 Projects in Ocean Engineering System Design (A)

Prereq.: 13.441, 13.411 or 13.412
G (1, 2, S)
Arr.

Determines design criteria for ocean-based systems such as ships, submersibles, platforms, etc., 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 is particularly encouraged. Primarily for graduate students in Ocean Engineering; others admitted by permission of instructor.
C. Chryssostomidis, M. S. Triantafyllou

13.463 Engineering System Design (A)

Prereq.: Permission of Instructor
G (2)
2-4-6

Develops basic techniques employed in planning and design of complex systems through involvement in a specific project. Develops specific background through lectures dealing with the selected project. Student results presented formally at the end of term. Each year's project announced during IAP.
C. Chryssostomidis

13.47J Multivariable Control Systems I (A)

(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, B. K. Walker

13.48J Multivariable Control Systems II (A)

(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 Control Applications in Ocean Engineering (A)

Prereq.: 13.47J, *13.48J*
G (2) **Not to be offered 1987-88**
Arr.

Modeling and control system design of ocean vehicles and structures. A complete design cycle to satisfy the mission objectives is required. Participation by several students in a single project is encouraged.
M. S. Triantafyllou

13.50 Numerical Methods with Applications to Marine Problems (Revised Content)

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. Roundoff error. Solution of linear systems. Non-linear 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 special methods. Assigned computer problems requiring familiarity with FORTRAN IV.
P. D. Sclavounos

13.51 Computer Models of Physical and Engineering Systems

Prereq.: 18.02, 8.01
U (1) 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) (New)

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)
3-0-6

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
A. W. Drake, A. R. Odoni

13.622J Mathematical Optimization Techniques (A)

(Same subject as 1.143J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Systematic survey of a broad spectrum of mathematical optimization techniques. Emphasis on formulation, solution methodology, algorithmic efficiency, and applications. Covers Lagrange multiplier and Kuhn-Tucker theory; duality; network problems; linear, integer, dynamic, stochastic, large-scale, and quadratic programming; and heuristics. Assumes some familiarity with linear algebra, calculus, and the computer.
H. N. Psaraftis, D. H. Marks

13.63J Advanced Reliability Analysis and Risk Assessment (A)

(Same subject as 22.40J)
Prereq.: 22.38, 22.82, 1.143J or 13.622J
G (2)
3-0-9

See description under subject 22.40J.
E. G. Frankel, N. Siu

13.631 Port Planning and Development (A) (Revised Content)

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, 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) (Revised Content)

Prereq.: 1.143J or 13.622J or 13.441 or 13.412
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) (New)

Prereq.: 6.041 or 18.444 or equiv.; 14.01 or 15.001 or equiv.; 13.622J or equiv.
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. Hierarchial decision models. Cross-impact analysis. Managing technological change in manufacturing. Case studies from manufacturing industries.
E. G. Frankel

13.661J Economics of Ocean Transportation (A)

(Same subject as 15.937J)
Prereq.: 14.120 or 15.012
G (2)
3-0-6

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.
H. N. Psaraftis, Z. S. Zannetos

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

13.68 Management of Marine Systems (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

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.
H. S. Marcus

13.685J Manufacturing/Technology Interface (A)

(Same subject as 3.565J, 15.365J)
Prereq.: Permission of Instructor
G (1)
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 which 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 interest of the student. Consult Department Student Administration Office for subject number which 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 student. Consult Department Student Administration Office for subject number which will be assigned by the Department in accordance with the technical area of the topic selected.
A. D. Carmichael

13.73 A Survey of Ocean Engineering

Prereq.: —
U (2)
1-0-1

Series of lectures acquaints undergraduate students in ocean engineering with the many facets of the field including naval architecture and marine engineering. Explores relationships and interfaces with the various engineering and scientific disciplines. Uses current problems and research projects for illustration. Each session conducted by a different faculty member, concentrating on that faculty member's area of interest. Undergraduate and graduate students from all departments are welcome.
T. F. Ogilvie.

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 1987-88**
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, (Woods Hole Staff): R. C. Spindel

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) **Next offered 1987-88**
3-1-8

See description under subject 12.534J.
A. B. Baggeroer, G. L. Duckworth

13.76 Introduction to Random Processes in Ocean Engineering (A)

Prereq.: 18.075
G (2) **Not to be offered 1987-88**
3-0-9

Fundamentals of random process theory and its application to physical and engineering problems. Elements of probability theory and statistics, harmonic analysis of deterministic and random processes, correlation, linear systems including those with frequency dependent paramaters such as ships in a seaway, analog and digital filtering, spectral analysis and extremal statistics. Applications include ocean waves, seakeeping, offshore structures in storms, and the establishment of design criteria.
J. H. Milgram

13.77J Invention

(Same subject as 2.941J, 16.671J)
Prereq.: —
G (1)
3-0-6

See description under subject 2.941J.
D. G. Jansson, A. D. Carmichael, W. R. Markey

13.771 Engineering Internship

Prereq.: —
U (1, 2, S)
0-6-0

13.772 Industrial Practice in Ocean Engineering

Prereq.: 13.771
U (1, 2, S)
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.
D. G. Jansson

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 exampies and application 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 (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

13.84J Flow Noise (A)

(Same subject as 2.065J, 16.082J)
Prereq.: 2.20 or 13.021 or 16.02
G (1) **Next offered 1987-88**
3-0-9

Elements of aerodynamics and hydrodynamic sound. Subsonic and supersonic jet noise. Jet noise suppression. Vortex sound and feedback resonance effects. Propeller, compressor, and helicopter rotor noise and noise suppression techniques. V/STOL noise, cavitation noise. Boundary layer noise. Match wave radiation, structural response, and reradiation. Alternate years.
P. Leehey

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 seawater. 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 1987-88**
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 1987-88**
3-0-9

Continues 13.861, treating ray and normal mode theory in greater depth, and introducing new topics. Emphasizes "state-of-the-art" level in ocean acoustics. Topics: 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

13.87 Wave Propagation in Random Media (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-9

Emphasizes physical principles and mathematical techniques common to most problems of wave propagation through and scattering in random media. The ocean and atmosphere as random medium. Scattering by discrete scatterers and by a continuous inhomogeneous medium. Statistics of the medium and the propagating wave. Single and multiple scattering, saturation. Geometric, Rytov, and parabolic approximations; path integral method; transport equations; propagation of moments. Given at MIT.
(Woods Hole Staff): Y. Desaubies

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 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 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.
R. K. Lester, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

13.92 Marine Policy (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Surveys major ocean uses and their associated policy issues; demonstrates relationships among uses and among the scientific, technical, economic, and political/legal aspects. Topics: law of the sea, seabed mining, offshore oil development, marine pollution, fisheries, and national security.
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. Ruina

13.94 Law for Ocean Systems (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

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.
J. D. Nyhart

13.97 Introduction to Technology and Law

Prereq.: —
U (1)
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. Topics: physical and ecological coastal processes; implications of the range of human activities that place demands on the limited coastal resource base; 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 test, 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 1987-88**
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. Given at Woods Hole Oceanographic Institute.
(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 1987-88**
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)

General Economics and Theory

14.UR Undergraduate Research

Prereq.: 14.02
U (1, 2)
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.
D. Quah

14.01 Economic Principles I

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.
F. M. Fisher, P. Temin

14.014J Engineering Aspects of Economic Analysis

(Same subject as 1.01J)
Prereq.: —
U (1)
4-0-8

See description under subject 1.01J. Credit is not given to both 14.014J or 1.01J. Consult R. V. D. Whitman.

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 ecomomies.
P. Krugman, S. Fischer

14.03 Applied Microeconomics

Prereq.: 14.01
U (1, 2)
3-0-6

Designed for non-majors 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: *R. S. Echaus*
Term 2: *W. C. Wheaton*

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 Humanities Requirement.
J. Moore

14.06 Intermediate Macroeconomic Theory

Prereq.: 14.02
U (1, 2)
4-0-8

Theory of national income determination, static and dynamic; components of aggregate demand; analysis of aggregate supply. Theory of growth and inflation.
Term 1: *O. J. Blanchard*
Term 2: *R. M. Solow*

14.07 History of Economic Thought

Prereq.: 14.01, 14.02
U (2) **Next offered 1987-88**
3-0-6

A selective historical survey of the development of economic analysis; gives varying degrees of attention to the contributions of Aristotle, Aquinas, Mun, Hume, Smith, Malthus, Ricardo, Marx, Mill, Walras, Marshall, Keynes, and Schumpeter.
P. Temin

14.08 Current Economic Problems

Prereq.: 14.01, 14.02
U (1) **Next offered 1987-88**
3-0-6

Discussion of selected economic problems and policies under current public consideration, such as stabilization, unemployment and inflation, capital formation, taxes, energy, agriculture, regulation, foreign trade and lending. Limited to 20.
E. C. Brown

14.09 Reading Seminar in Economics

Prereq.: 14.04, 14.06
U (1)
Arr.

Reading and discussion of particular topics in economics. Open to undergraduate students by arrangement with individual faculty members. Consult Department headquarters.
L. J. Taylor

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

14.110J Applied Microeconomic Analysis (A)

(Same subject as 1.147J)
Prereq.: 14.01
G (1) **Next offered 1987-88**
3-0-6

For students with primary interests outside of economics who wish to acquire some expertise in applied economic analysis. Development of microeconomic theory at an intermediate level, including consumer and producer theory, imperfect competition, capital and welfare economics, emphasizing applications of particular relevance to engineers, such as problems related to transportation, energy, water resources, and constructed facilities. Credit not given for this subject and 14.03, 14.04.
W. C. Wheaton

14.111J Economics of Project Evaluation (A)

(Same subject as 1.148J)
Prereq.: 14.03 or 14.120
G (2)
3-0-6

Economic concepts of costs and benefits: consumers' and producers' surplus; shadow prices; and valuation of non-market 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

14.120 Microeconomic Theory (A)

Prereq.: 14.03
G (1) **Next offered 1987-88**
3-0-9

Comprehensive survey, emphasizing more advanced aspects as compared with similar undergraduate subjects. Equilibrium of the household, the firm, and markets with various degrees of competition and monopoly. Resource allocation and income distribution in static general equilibrium. Capital, interest, and dynamic equilibria. Cost-benefit analysis and welfare economics.
Staff

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.
O. D. Hart

14.122 Microeconomic Theory II (A)

Prereq.: 14.04
G (1)
2-0-4

Theory of consumption and general equilibrium.
F. M. Fisher

14.123 Microeconomic Theory III (A)

Prereq.: 14.122
G (2)
2-0-4

Fundamental welfare theorem, externalities, public goods, second-best analyses.
M. L. 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) (Revised Unit)

Prereq.: 14.04
G (1)
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)

Prereq.: 14.122
G (2)
2-0-4

A brief introductory review followed by dynamic games, incomplete information, refinement, and reputation. Applications are drawn from industrial organization, auctions, bargaining, labor markets, and internal organization. Half-term subject.
R. Gibbons

14.127 Economics of Uncertainty (A)

Prereq.: 14.124
G (2)
3-0-9

Individual behavior under uncertainty. Equilibrium and welfare with uncertainty. Search and information.
J. Moore, E. Sheshinski

14.128 Mathematical Optimization and Economic Theory (A)

Prereq.: 14.124
G (1) **Next offered 1987-88**
2-0-4

Linear and nonlinear programming, duality theory, dynamic programming, and optimal control. Half-term subject.
M. L. Weitzman

14.130 General Equilibrium (A)

Prereq.: 14.04
G (2) **Next offered 1987-88**
2-0-4

Continuation of 14.125. Half-term subject.
Staff

14.132 Schools of Economic Thought (A)

Prereq.: 14.04
G (2) **Next offered 1987-88**
3-0-9

Historical development of economics, as illustrated by selected writers: Aristotle, Aquinas, Hume, Smith, Ricardo, Malthus, Mill, Marx, Walras, Marshall.
Staff

14.141 Disequilibrium Foundations of Equilibrium Economics (A)

Prereq.: 14.122
G (2) **Next offered 1987-88**
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 question. Half-term subject.
F. M. Fisher

14.142 Advanced Topics in Optimization (A)

Prereq.: 14.128
G (1) **Next offered 1987-88**
2-0-4

Applications of optimization theory to economic model building, including activity analysis, input-output theory, stochastic control, and optimal growth theory. Half-term subject.
M. L. Weitzman

14.144 Applied Price Theory (A)

Prereq.: 14.122
G (2) **Next offered 1987-88**
Arr.

Selected topics in price theory, focus changing from year to year. Currently emphasizes the economics of exhaustible and renewable natural resources.
R. M. Solow

14.147 Economic Applications of Game Theory (A)

Prereq.: 14.126
G (2)
2-0-4

See 14.126. Except under special circumstances, students are advised to take both 14.126 and 14.147. Half-term subject.
R. Gibbons

14.148 Advanced Topics in Microeconomic Theory (A)

Prereq.: 14.124
G (1) **Next offered 1987-88**
Arr.

14.149 Advanced Topics in Microeconomic Theory (A)

Prereq.: 14.124
G (2) **Next offered 1987-88**
Arr.

Advanced topics in microeconomic theory of current interest. Consult Department headquarters.

14.191 Economic Analysis of Law (New)

Prereq.: 14.04
G (2)
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

14.192 Models of Political Economy (A) (Revised Unit)

Prereq.: 14.121
G (2)
3-0-6

Political economy is the study of group or collective decision-making processes and the institutions society employs to implement these processes. Emphasizes positive rather than normative theory and empirical applications. Includes collective choice theory, interest group competition, theories of legislative behavior, bureaucracy, behavior of administrative agencies, ideology and altruism.
P. L. Joskow

14.193 Seminar: Topics in Economics (A)

Prereq.: 14.121, 14.451
G (1, 2) **Next offered 1987-88**
Arr.

14.194 Seminar: Topics in Economics (A)

Prereq.: 14.121, 14.451
G (2)
Arr.

Economics of contracts including labor contracts under symmetric and asymmetric information, repeated contracts, self-enforcing contracts, incomplete contracts and the theory of the firm, legal approaches to breach of contract.
O. D. Hart

14.195, 14.196 Reading Seminar in Economics (A)

Prereq.: 14.121
G (1, 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.

14.198, 14.199 Teaching Introductory Economics

Prereq.: —
G (1, 2)
2-0-2

Required of teaching assistants in introductory economics (14.01 and 14.02) under the supervision of the faculty member in charge of the subject.
14.198: *F. M. Fisher, P. Temin,*
14.199: *P. Krugman, S. Fischer*

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, anti-trust policy, and public utility regulation.
R. Gibbons

14.21J Health Economics

(Same subject as HST 901J)
Prereq.: 14.01
U (1) HASS
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)
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.
O. D. Hart

14.271 Problems in Industrial Economics (A)

Prereq.: 14.04
G (1)
3-0-9

Small and large enterprises in the American economy; market structures; degrees of monopoly and competition; requisites of public policy.
P. L. Joskow, J. M. Tirole

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 anti-trust policy, public utility regulation, consumer protection, environmental policy, peak load pricing, and public enterprise.
N. Rose, R. Schmalensee

14.286J Health Economics Seminar (A)

(Same subject as HST 903J)
Prereq.: 14.04
G (2) **Next offered 1987-88**
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)
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.
G. Saloner, J. M. Tirole

14.292 Antitrust Seminar (A)

Prereq.: 14.271
G (1)
3-0-6

Discussion of economic issues as they arise in actual anti-trust cases. Emphasis on cases in which the instructor has participated including (but not limited to) the IBM anti-trust cases. Students expected to construct and criticize economic testimony in the context of the facts of an actual case.
F. M. Fisher

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 Humanities Requirement.
Term 1: *D. Quah*
Term 2: *J. Moore*

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 Humanities Requirement.
Term 1: *H. S. Farber*
Term 2: *J. Wooldridge*

14.381 Statistical Method in Economics

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

14.383 Econometrics II (A)

Prereq.: 14.382
G (1)
4-0-8

Theory and economic applications of the linear multiple regression model. Identification and structural estimation in simultaneous models. Analysis of economic policy and forecasting in microeconomic models.
14.382: *F. M. Fisher, D. L. McFadden*
14.383: *J. L. Powell, J. Wooldridge*

14.384 Time-Series Analysis (A)

Prereq.: 14.382 or 14.388
G (1)
2-0-4

Theory and applications of time-series models, including stochastic processes, ARIMA processes, spectral analysis, and distributed lags.
D. Quah

14.386 Advanced Topics in Time Series (A) (Revised Unit)

Prereq.: 14.383
G (1)
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

14.387 Topics in Advanced Econometric Theory (New)

Prereq.: 14.382, 14.383
G (2) **Next offered 1987-88**
2-0-4

Special topics in advanced econometric theory.
J. L. Powell

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.
J. Wooldridge

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 (Revised Unit)

Prereq.: 14.04, 14.06, 14.31
U (1)
3-0-9

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.
O. J. Blanchard

14.391 Workshop in Economic Research (A)

Prereq.: 14.124, 14.454
G (1)
2-0-10

14.392 Workshop in Economic Research (A)

Prereq.: 14.124, 14.454
G (2)
2-0-10

Develops research ability of students through intensive discussion of dissertation research as it proceeds, carrying out of 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.

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 1987-88**
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)
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, S. M. Fischer.

14.452 Macroeconomic Theory II (A)

Prereq.: 14.451
G (2)
2-0-4

Determination of aggregate output, employment, and prices. Keynes and alternate theories. The Phillips Curve. Inflation in the short and long run. Half-term subject.
R. Dornbusch, S. M. Fischer

14.453 Macroeconomic Theory III (A)

Prereq.: 14.452
G (1)
2-0-4

Theory of involuntary unemployment; sources of wage and price stickiness; role of expectations. Half-term subject.
O. J. 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) (Revised Unit)

Prereq.: 14.454
G (2)
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 macro-econometrics, 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)
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

Basic models of money and monetary economics; business cycles and the role of expectations; consumption and investment decisions under uncertainty; asset pricing models with special reference to equities and the term structure of interest; price bubbles.
O. J. Blanchard, S. M. Fischer, J. Rotemberg

14.463 Monetary Economics II

Prereq.: 14.122, 14.452
G (2)
3-0-9

The Phillips curve and models of wage and price determination; banking and financial intermediation; monetary and fiscal policy.
O. J. Blanchard, S. M. Fischer, J. Rotemberg

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.
E. Sheshinski

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

14.474 Fiscal Economics III (A)

Prereq.: 14.124
G (2) **Next offered 1987-88**
2-0-4

Topics of current research interest in advanced fiscal theory, such as optimal taxation, optimal expenditure policy, policies to deal with externalities. Half-term subjects.
J. M. Poterba

14.476 Social Insurance (A)

Prereq.: 14.121, 14.122
G (2) **Next offered 1987-88**
3-0-9

Theory of social insurance and examination of some of 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)
3-0-9

Modern theories and empirical studies of the determinants of the distribution of income.
L. C. Thurow

14.490J Advanced Topics in Financial Economics (A) (New)

(Same subject as 15.440J)
Prereq.: 15.415
G (1, 2)
3-0-6

See description under subject 15.440J.
C-F. Huang

International, Interregional, and Urban Economics

14.50 State and Local Government Finance

Prereq.: 14.01
U (2) **Next offered 1987-88**
3-0-6

Issues in state and local government finance, paying particular attention to role of labor costs and labor relations. Topics include urban fiscal crisis, school finance reform, public sector impasses, and impacts of public employee unions.
W. C. Wheaton

14.51J Urban Economics

(Same subject as 11.008J)
Prereq.: 14.01
U (1)
3-0-6

Analyzes urban problems in 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.
J. Rothenberg

14.53 Comparative Economic Systems

Prereq.: 14.02
U (1)
3-0-6

Comparative study of the treatment of economic problems under different economic systems. Analyzes the economic ideology of capitalism, utopian writings, market socialism, workers' management, and Marxism. Functions of prices, profits, and planning in allocation of resources. Compares several capitalist and socialist countries including the US and Yugoslavia.
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) (Revised Content)

(Same subject as 1.283J, 11.410J)
Prereq.: 14.04
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.: 11.410J or 14.573J
G (2) **Next offered 1987-88**
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 its effect 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

Prereq.: —
U (1, 2) HUM-D
3-0-6

Introductory analysis, through an integrated social science approach, of the nature of labor problems in an industrial society; emphasizing unemployment, participation in the labor force, development of labor organizations, accommodation of management and unions through the dynamic bargaining process, industrial conflict, and other selected issues arising between management and labor in American society.
Term 1: *L. Lynch*
Term 2: *M. J. Piore*

14.64 Labor Economics and Public Policy

Prereq.: 14.01
U (2)
3-0-6

Theory and evidence concerning the functioning of the labor market. Particular emphasis on the roles played by government and unions. Topics: 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 (2)
3-0-6

Introduction to labor economics stressing alternative approaches to labor market analysis. Special attention to theories of worker motivation and behavior, to the structure of labor markets, to the determinants of wage levels and unemployment, and to the historical evolution of labor market institutions.
M. J. Piore

14.672J Labor Economics II (A)

(Same subject as 15.672J)
Prereq.: 14.04
G (1)
3-0-6

Neoclassical analysis of the labor market and its institutions. A systematic development of the theories of labor supply, labor demand, and human capital. Also theories of wage and employment determination over the life cycle, including search and contract theories, and the analysis of labor unions. Emphasis on the empirical evidence and applications to policy issues throughout.
H. S. Farber, R. Gibbons

14.673J Labor and Public Policy (A)

(Same subject as 15.673J)
Prereq.: 14.64
G (2)
3-0-6

Economic analysis of labor problems that are the focus of public policy with emphasis on the development of appropriate conceptual frameworks and the evaluation of relevant empirical evidence. Includes discrimination, incomes policies, health and safety regulation, minimum wages, theories of unemployment, employment and training programs, and collective bargaining in the private and public sectors.
H. S. Farber

14.674J Comparative Systems of Industrial Relations and Human Resource Development (A)

(Same subject as 15.674J, STS 512J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

See description under subject 15.674J.
M. J. Piore

14.691J Research Seminar in Industrial Relations (A)

(Same subject as 15.691J)
Prereq.: 14.671J or 14.672J
G (1)
3-0-6

14.692J Research Seminar in Industrial Relations (A)

(Same subject as 15.692J)
Prereq.: 14.691J
G (2)
3-0-6

See description under subject 15.691J, 15.692J. Information: R. V. McKersie

Economic History

14.71 Topics in Economic History

Prereq.: 14.02
U (1) HUM-D
3-0-6

Applies economic analysis to historical problems. Topics vary from year to year. In the past they included "The Economic Effects of the Black Death," "The Economic Causes of Slavery and Serfdom," and others. The focus this year is on the US. Limited to 20. Some knowledge of history desirable.
B. De Long

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 to 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 argicultural colony to a manufacturing power. Consideration of both microeconomic (railroads, slavery, tariffs) and macroeconomic (wars, the Depression) topics. Comparison with other economies.
P. Temin

14.733 Topics in European Economic History (A)
(New)

Prereq.: 14.04, 14.06
G (2) **Next offered 1987-88**
3-0-9

Various aspects of the European experience. Includes industrialization, the effect of wars on national economies, the effect of macroeconomic policies, the impact of the Depression, the postwar recovery.
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

14.774 Technology and Development (A)

Prereq.: 14.74
G (2) **Next offered 1987-88**
3-0-9

A survey, for noneconomics majors, of issues in identifying, choosing, and using particular technologies in developing countries and consequences of decisions made. Topics: economic analysis of implications of social, political, and technological criteria and constraints on choice in rural as well as urban production conditions. International transfer and adaptation of technology, including role of transnational corporations. Case studies develop and illustrate problems.
R. S. Eckaus

14.776 Theory and Problems of Economic Development (A)

Prereq.: 14.02
G (2) **Next offered 1987-88**
3-0-9

For noneconomics majors a survey and analysis of problems of developing countries. Special attention to interrelationships between agricultural and industrial sectors and urban-rural migration, analysis of dual economies in development processes, resource allocation, international trade and development problems, monetary and structural changes, applications of cost-benefit analysis and planning models for development.
R. S. Eckaus

14.778J Theories of Economic Development (A)
(New)

(Same subject as 11.486J)
Prereq.: *11.210*
G (1)
3-0-6

See description under subject 11.486J.
L. 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 non-neoclassical (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)
3-0-9

See description under subject 17.156J.
S. Berger, M. J. Piore

14.782 Comparative Economic Systems (A)

Prereq.: 14.121, 14.451
G (2)
3-0-9

Comparative study of capitalism and socialism, including market socialism, workers' management (in Yugoslavia), Marxism and centrally-planned economies, emphasizing the Soviet Union. Soviet industrialization debates and growth models. Development of the Soviet economy. Management of agriculture and industry. Prices and wages. Measures of relative efficiency. Comparisons with China.
M. L. Weitzman

15 **Management**

Managerial Economics

15.UR Undergraduate Research

Prereq.: —
U (1, 2)
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.
L. McAlister

15.001 Managerial Economics

Prereq.: —
U (1, 2)
4-0-8

Introduces micro and macroeconomics emphasizing model building and applications. Mechanisms of supply and demand and economics of consumer and business decisions. Operation of the price-profit system. Market structures and market behavior in specific industries. Determination of national income, aggregate level of economic activity, and interest rates. Introduces fiscal and monetary policy. Analyses of economic problems of relevance to management.
N. L Rose

15.002 Introduction to Managerial Economics (New)

Prereq.: —
G (1)
2-0-4

Introduces basic principles of micro and macroeconomics and applies them to management decision making and anlaysis of public policy. Restricted to graduate students in Sloan School of Management.
N. L. Rose

15.011 Applied Microeconomics

Prereq.: 14.01 or 15.001
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 or 15.001
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, international debt problem and world financial system.
J. J. Rotemberg, L. C. Thurow

15.013 Industrial Economics for Strategic Decisions (A)

Prereq.: 15.011
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 non-price competition; dynamic pricing, output, and advertising decisions; entry and entry deterrence; evolution of industries.
R. S. Pindyck, R. L. Schmalensee, E. R. Berndt, 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 1987-88**
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 which these actions create. Sample applications in energy and natural resources, environmental control, industrial promotion. Content relevant to private firms, public agencies, and their consultants.
H. D. Jacoby

15.017 Economics of Government Regulation (A)

Prereq.: 15.011
G (2)
3-0-6

Considers rationale, origin, and effects of the major forms of government regulation of firms and markets. Uses experience in the US to illustrate principles and problems. Economic and political foundations, ideal and actual public utility regulation, utility regulation applied to competitive markets, new policies aimed at health, safety, consumer protection, and environmental preservation.
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

15.019 Energy Economics and Policy (A)

Prereq.: 15.011
G (1)
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: H. D. Jacoby

15.024 Applied Economics for Managers (Revised Content and Unit)

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 the changing US and international business environment. 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 emphasizing 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
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

15.041 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.
Consult: J. J. Rotemberg

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 programming, integer programming, and nonlinear programming. Solving problems by computer and interpreting the results. 15.058 is more advanced than 15.062 and substitutes for it.
J. B. Orlin

15.059 Mathematical Programming Models and Applications (A) (New)

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, 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, M. A. Wong

15.062 Decision Support Systems III

Prereq.: 15.061
G (1, 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.: Permisison 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 high degree of uncertainty and sophisticated competitors.
G. M. Kaufman

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

15.073J Introduction to Stochastic Processes (A)

(Same subject as 18.445J)
Prereq.:18.313 or 18.440 or 6.041
G (1, 2)
4-0-8

See description under subject 18.445J.
Information: R. M. Dudley

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.
R. E. Welsch, M. A. Wong

15.076J Statistics for Model Building (A)

(Same subject as 18.457J)
Prereq.: 15.075 or 18.443, 18.06
G (2)
3-0-9

Linear and nonlinear regression analysis emphasizing detection and correction of model failures and variable selection. Robust methods, bootstrap, jackknife, and cross-validation. Data transformation, graphics, and non-parametric multiple regression. Topics illustrated on actual case material. Heavy use of statistical computer packages.
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 algorithms and their efficiency; algorithms for shortest routes, minimum cost flow, minimal spanning trees, traffic equilibrium, vehicle routing and the traveling salesman problem, facility location and network design, matching. Implementation issues.
T. L. Magnanti, J. B. Orlin

15.083 Combinatorial Optimization (A)

Prereq.: 15.081J
G (1)
3-0-6

Devoted to integer programming and related topics. Group optimization methods and integer programming duality theory. Benders' method for mixed integer programming. Introduction to combinatorics including matroids, properties of integer polyhedra, theory of computational complexity, optimization of submodular functions.
J. B. Orlin

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 concerned with current issues in Operations Research. Typical topics: reports of research projects, proposed or in progress, 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

Health Care Management

15.121 Seminar in Health Management (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

15.122 Seminar in Health Management (A)

Prereq.: Permission of Instructor
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. Others admitted by permission of instructor.
N. S. Stearns, E. B. Roberts

15.136 Health Technology (A)

Prereq.: Permission of Instructor
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

15.141J Comparative Health Systems (A)

(Same subject as 17.228J)
Prereq.: Permission of Instructor
G (1)
3-0-6

See description under subject 17.228J.
S. N. Finkelstein, H. M. Sapolsky

15.144 Analytical Methods for Health Policy and Management (A)

Prereq.: Permission of Instructor
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

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. Role of public policies in global competition and their interaction with corporate strategies. Restricted to Sloan Fellows.
D. R. Lessard

15.221 International Business Management I (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Introduces global regulatory and competitive environment within which international business transactions take place, and the role and behavior of the multinational firm as it responds to its own internal dynamics and the external environment. Examines interface between multinational firm and the nation-state, identifying points of potential conflict and cooperation. Draws on examples from various countries and industries.
D. F. Simon

15.222 International Business Management II (A)

Prereq.: 15.221
G (1)
3-0-6

Analyzes internal structures and processes of the multinational firm in context of global regulatory and competitive environment. Emphasizes managing information flows, formulating and implementing strategy, developing and maintaining required social resources, and designing effective organizational structures.
D. E. Westney

15.223 International Business Environments (A)

Prereq.: 15.221
G (1)
3-0-6

Analyzes social and political environments of the multinational firm at advanced level. Theory and practice of environmental scanning function and its interaction with other organizational processes. Compares processes of environmental adaptation of US and Japanese multinational firms. Information: D. E. Westney

15.224 Intercultural Communication I (A)

Prereq.: 15.221
G (2)
3-0-6

15.225 Intercultural Communication II (A)

Prereq.: 15.224
G (1)
3-0-6

Vehicle to provide academic credit for independent study involving in-depth exposure to culture with which student has had no significant prior exposure. Typically includes language training, special project carried out during three months of foreign residence, and written report based on experience. Information: D. E. Westney

15.227 International Technology Transfer (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Examines technology flows among countries focusing on transfer issues in: East-West relations and export controls; third world development; international competition and technology transfer among industrialized nations; technology exchanges among third world nations. Emphasizes role of multinational firm as purveyor of technology; examines licensing of technology, co-production, patents. Analyzes experiences of different countries for sources of past problems and ways of avoiding future problems.
D. F. Simon

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

History and Environment

15.268 Readings in Power and Responsibility (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Studies managerial power and responsibility in relation to today's world. Examines conflicts between power and moral responsibility, the value-complexes which 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

15.269 Business and the Media (A)

Prereq.: Permission of Instructor
G (1)
2-0-4

Studies interrelationships of business and the media, to provide managers with a realistic understanding of journalistic reporting and interpretation as it affects corporate practice. Divided into sessions dealing with editorial viewpoints as reflected in the media, discussions with appropriate editors and correspondents, and corporate responses obtained from published records and meetings with corporate public affairs officers from major firms. Restricted to Sloan Fellows and second-year graduate students.
L. L. Banks

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, M. Piotrowski

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 communication skills important to managers, including running and contributing productively to meetings, listening, and being interviewed by news media. 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, Jr., 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. E. 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); 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. E. Van Maanen*

15.312 Managerial Decision Making and Leadership (A)

Prereq.: 15.301 or 15.311
G (1)
3-0-6

Examines individual managerial behavior within organizations. Includes: judgment and choice, individual decision style, causal reasoning, decision aids, motivation, and leadership. Students without stated prerequisites may enroll with permission of instructor.
J. S. Carroll

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, fieldwork, weekly learning group exercises, and written assignments students learn not only the concepts but also how to improve their own communication and group membership. Students without stated prerequisites may enroll with permission of instructor.
E. H. Schein

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. Information: J. E. Van Maanen

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, particularly Japan. Designed for advanced master's and doctoral students.
D. E. Westney

15.322 Organizational Psychology (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Analyzes — through lectures, discussions, and class exercises — management of human resources in industry. Restricted to Sloan Fellows.
J. E. Van Maanen, E. H. Schein

15.337 Sociology of Work and Organizations (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

Reviews key concepts and research findings from sociology which illuminate the nature of work, how organizations evolve, and managerial process. Practice in use of sociological methods for studying work and organizations both in public and private sector. Designed for advanced master's and doctoral students.
J. E. Van Maanen

15.339 Social Psychology of Work and Organizations (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
3-0-6

Reviews key concepts and research findings from social psychology which 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.
J. S. Carroll

15.341 Seminar in Behavioral Sciences

Prereq.: —
G (1)
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. E. 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: E. H. Schein

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)
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 project based on a common data base 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.: Permission of Instructor
G (2) **Next offered 1987-88**
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

Management of Technology and Innovation

15.351 Managing Technology and Innovation (A)

Prereq.: 15.301 or 15.311, 15.501 or 15.515
G (2)
3-0-6

Wide range of topics in corporate management of technology and innovation. Issues related to managing technical function and central R&D lab, including project management, lab management systems and structure, project selection, technological forecasting, and management of technical personnel. Technical interface issues, such as the relationships among marketing, manufacturing, and R&D. Topics central to general study of innovation, such as entrepreneurship and venture management. Information: E. B. Roberts

15.355 Managing Technological Innovation (A)
(New)

Prereq.: Permission of Instructor
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.
E. B. Roberts

15.361 Managing Professionals

Prereq.: —
G (S)
3-0-6

Examines human side of management 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. Primarily for members of the Management of Technology Program. Others admitted by permission of instructor.
R. Katz

15.365J Manufacturing/Technology Interface (A)

(Same subject as 3.565J, 13.685J)
Prereq.: Permission of Instructor
G (1)
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. Primarily for members of the Management of Technology Program. Others admitted by permission of instructor.
J. M. Utterback

15.367 Marketing/Technology Interface (A)

Prereq.: 15.361 or 15.810 or 15.812
G (2)
3-0-6

Market inputs to product research, design, and development. Market research techniques for new product development. User role as source of innovations in industrial goods. Marketing of advanced technology products and systems. Primarily for members of the Management of Technology Program. Others admitted by permission of instructor.
E. A. von Hippel, G. L. Urban

15.369 Corporate Strategies for Managing Research, Development, and Engineering (A)

Prereq.: 15.351 or 15.361
G (2)
2-0-7

Joint seminar with the Harvard Business School technology management group. Strategic issues in managing research, development, and engineering. Considers corporate research laboratories, new venture organizations, and integration of RD & E into corporate strategy. Lecture sessions by faculty of both schools and by invited speakers from government and industry. Independent study and preparation of reports by individual students or teams of students.
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, Jr.

15.375 New Enterprises (A)

Prereq.: Permission of Instructor
G (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.
E. A. von Hippel

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, J. E. Parsons

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; 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.
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. C. Cox, 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.
T. A. Marsh

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. S. Ruback

15.418 Taxation and Business Management (A)

Prereq.: 15.410 or 15.412 or 15.415
G (1, 2) **Next offered 1987-88**
3-0-6

Analyzes effect of taxation on conduct of business. Concentrates on major decisions in which 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.
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.
F. Modigliani

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.
T. A. Marsh

15.434 Capital Investment Decisions (A)

Prereq.: 15.415
G (1, 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. Forecasting, mergers, OR and planning models, public investment decisions.
R. S. Ruback, C-F. Huang

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.
S. C. Myers

15.436 International Managerial Finance (A)

Prereq.: 15.012, 15.415
G (1)
3-0-6

Examines factors which 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 the industry deals with. Description of trading and hedging techniques. Analysis of new financial products and procedures.
R. C. Merton

15.440J Advanced Topics in Financial Economics (A)

(Same subject as 14.490J)
Prereq.: 15.415
G (1, 2)
3-0-6

Surveys theory and current research in financial economics. Primarily for doctoral students in finance, economics, and accounting. Reviews continuous-time asset pricing models, contingent claims valuation, empirical work on capital asset pricing and market efficiency, and new developments in the theory of corporate investment and financing decisions.
C-F. Huang

15.441 Research Seminar in Finance (A)

Prereq.: 15.415
G (1, 2)
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.
F. Modigliani

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 Financial and Cost 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 and cost accounting concepts, and methods of financial analysis. Examines financial goal structures and decision-making processes which give rise to information needs.
P. C. O'Brien

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). Emphasizes use of accounting information in decision making, performance evaluation, and control in organizations. Restricted to Sloan Fellows.
J. M. McInnes

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 goal structures and decision-making processes which give rise to information needs. 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, S. Krishnamurthi

15.516 Financial and Cost Accounting (A except XV)

Prereq.: Permission of Instructor
G (1, 2)
3-0-6

Meets with 15.501. Term paper required.
P. C. O'Brien

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.
R. T. S. Ramakrishnan

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.).
S. Krishnamurthi

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 multi-dimensional measurement. Coordination of responsibility centers, and transfer pricing mechanisms. Content of 15.521 relevant but not required.
Information: R. T. S. Ramakrishnan

15.539 Special Seminar in Accounting, Planning, and Control (A)

Prereq.: 15.515
G (1, 2)
Arr.

Opportunity for group study by graduate students on current topics related to accounting, planning, and control not otherwise included in curriculum.
P. Healy

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 concerned with 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. Primarily for doctoral students.
P. Healy

Management Information Systems

15.560 Decision Support Systems I

Prereq.: 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.
M. E. Treacy, T. W. Malone

15.562 Principles of Management Information Systems (A)

Prereq.: 1.00 or 2.10 or 15.560
G (1, 2)
3-0-6

Introductory examination of issues related to effective use of computer-based information systems in organizations. Topics: technology (computer sysems 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.
J. A. Meldman, H-M. D. Toong

15.564 Management Information Technology I (A)

Prereq.: 1.00 or 2.10 or 15.560
G (1, 2)
4-0-8

Introduces principles of computer systems and computer systems programming. Emphasizes program planning and organization. Topics: machine language, assemblers, compilers, and operating systems. Algorithms presented for translation from programming languages to machine languages, table processing, searching, sorting, and storage management. Requires students to prepare and test several programs written in System/370 Assembly Language and PL/I.
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 which 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

Focus 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 on-going organizations. Lectures, cases, projects, and analysis of existing decision support systems.
M. E. Treacy

15.571 Advanced Computer Systems (A)

Prereq.: 15.564
G (2)
3-0-6

Operating systems and their interface to various levels of hardware and software. System architecture, new technologies, and operating systems services (storage, processors, data management, and I/O supervision). Other topics: virtual machines, multiprocessor systems, performance measurement, data security. Discusses microsystems and personal and traditional mainframe systems. Assumes knowledge of Assembler Language programming. Requires class participation and readings.
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.

15.579 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 data-banks, 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 concerned with 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, M. E. Treacy

Law

15.601 The American Legal System

Prereq.: 14.02 or 15.001 or 15.012
U (1) HASS
3-0-6

Meets with 15.611.
J. A. Meldman

15.611 The American Legal System (A)

Prereq.: Prereq.: 14.02 or 15.001 or 15.012
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

15.612 Business and the Law

Prereq.: —
G (2)
3-0-6

Emphasizes current legal problems of concern to the business executive. Analyzes torts, contracts, product liability, antitrust aspects of marketing, and cases pending before the Supreme Court. Attention to the impact on managers of actions by administrative agencies such as the NLRB, FTC, and EPA; the procedural requirements that govern their rule making; and the role of courts in resolving disputes between government and business.
G. F. Bloom

15.625 Government Regulation in the Workplace (A)

Prereq.: 14.01 or 15.012
G (2)
3-0-6

Public policy on employment relationship and operation of labor market. Topics: employee wages, benefits, and pensions; employee health and safety; equal employment opportunity and affirmative action; due process in terminating employment relationship, collective bargaining and administration of bargaining agreement; social insurance programs; manpower training and development programs. Considers legal, political, and sociological perspectives on these issues.
K. G. Abraham

15.631 Corporate Law for the Modern Manager (A)

Prereq.: Permission of Instructor
G (1)
3-0-6

Examines legal and ethical obligations that arise between the individual (employee, manager, officer, director), the corporation, and the world. Seminar covers the formation and legal organization of various types of businesses, with particular emphasis on corporations; obligations of corporation to outside world based on the activities of its employees, managers and owners; obligations of individuals serving in those capacities to corporation and outside world; corporate securities; and regulation of corporate ownership and control.
J. F. Vittek, Jr.

15.635 International Law and Regulatory Order (A)

Prereq.: Permission of Instructor
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.: Permission of Instructor
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.
J. D. Nyhart, G. F. Bloom

15.649 Special Seminar in Law (A)

Prereq.: 15.601 or 15.611
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

Industrial Relations and Human Resource Management

15.660 Industrial Relations and Human Resource Management

Prereq.: —
G (2)
2-0-4

15.662 Industrial Relations and Human Resource Management (A)

Prereq.: 15.511
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.: 15.301 or 15.663
G (2)
2-0-7

Seminar emphasizing managerial responsibilities and policies in the effective utilization of people in organizations. Topics: managers and their personnel concepts, management organization for personnel administration, organization planning and management development, manpower planning and personnel budgets, recruitment and selection, promotion and transfer, training, performance appraisal, discipline, managing change, and wage and salary administration. Field research on selected problems.
L. M. Lynch

15.665 Power and Negotiation (A)

Prereq.: 15.663
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

15.671J Labor Economics I (A)

(Same subject as 14.671J)
Prereq.: 14.64 or 15.663
G (2)
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 (1)
3-0-6

See description under subject 14.672J.
H. S. Farber, R. Gibbons

15.673J Labor and Public Policy (A)

(Same subject as 14.673J)
Prereq.: 14.64
G (2)
3-0-6

See description under subject 14.673J.
H. S. Farber

15.674J Comparative Systems of Industrial Relations and Human Resource Development (A)

(Same subject as 14.674J, STS 512J)
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 in 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

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.: 15.671J or 15.672J
G (1)
3-0-6

15.692J Research Seminar in Industrial Relations (A)

(Same subject as 14.692J)
Prereq.: 15.691J)
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.
G. R. Bitran, L. Li, S. C. Graves, C. H. Fine

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: inventory theory, sequencing theory, aggregate production planning, production scheduling, large-scale system methodology, decomposition theory, and aggregation methods. Research on heuristic methods.
S. C. Graves

15.765 The Operating Manager (A)

Prereq.: Permission of Instructor
G (2)
3-0-6

Develops operating skills of a manager through case analyses and discussions. Cases drawn primarily from manufacturing situations and 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. Consult: G. R. Bitran

15.767 Industrial Project Evaluation (A)

Prereq.: Permission of Instructor
G (2)
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. Consult: 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

15.795 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 concerned with 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 sampling of 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.
L. McAlister, D. L. Marlino

15.811 Marketing (A)

Prereq.: 15.071, 15.511
G (1)
3-0-6

Analyzes elements of marketing strategy which can be utilized by business, governmental, and social organizations to meet 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.
J. R. Hauser

15.820 Advanced Marketing Management (A) (New)

Prereq.: 15.810 or 15.812
G (2)
2-0-4

Concentrates on marketing strategy. Lectures, 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, case discussions, projects.
D. L. Marlino

15.825 Marketing Models (A)

Prereq.: 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

15.826 Industrial Marketing (A)

Prereq.: 15.810 or 15.812
G (2)
3-0-6

Focus on marketing goods and services to organizations for resale to other industrial customers or for use in the goods and services they, in turn, produce. Literature on organizational buying behavior provides the foundation of the subject. Topics: industrial marketing analysis, product planning, distribution and channel decisions, promotion and advertising, sales force decisions. Emphasizes using models and research results to solve industrial marketing problems. Lectures, case discussions, research project. Information: G. L. Urban

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. 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. Requires term project.
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.
L. McAlister

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. Information: G. L. Urban

15.839 Workshop in Marketing

Prereq.: Permission of Instructor
G (1, 2)
Arr.

Presentations by faculty, doctoral students and guest speakers of ongoing research concerned with 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.: Permission of Instructor
G (1, 2)
3-0-9

Introduces principles for modeling dynamic social and industrial systems. Emphasizes building intuitive understanding of feedback structures underlying growth, stagnation, and cyclical fluctuation. Focus on system dynamics as one approach to understanding behavioral characteristics of complex systems. Student exercises treat feedback system behavior, reasons for shifting modes of behavior, and model formulation. Modeling assignments illustrate applicability of basic concepts to biological, economic, ecological, industrial, and urban systems. Tutorial session arranged for 15.852.
J. D. Sterman

15.873 Principles of Dynamic Systems II (A)

Prereq.: 15.872
G (2)
3-0-9

Continues philosophy and methods of 15.872 with purpose of expanding student's ability to 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.
J. D. Sterman

15.874 System Dynamics for Business Policy (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Introduces modeling of corporate and industrial systems. Examines separate functional areas of production planning, labor management, capital investment, marketing, finance and accounting. Functional area models pieced together to analyze the cause of such corporate problems as production and employment instability, loss of market share, unstable market growth, and declining profitability. Develops skills in portraying complex managerial systems, and deriving understanding through quantitative modeling and computer simulation.
J. D. Sterman

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15.875 Applications of System Dynamics (A)

Prereq.: 15.872 or 15.874
G (2)
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.
J. D. Sterman

15.878 Economic Dynamics (A)

Prereq.: 15.872
G (1)
3-0-6

Introduces system dynamics modeling of economic systems focusing on simple generic structures identified in the System Dynamics National Project. Combines lectures, exercises, and a term project on subject of student's choice. Topics: economic cycles; inflation and unemployment; capital investment and monetary policy; energy-economy interaction; and the economic long wave.
J. D. Sterman, P. M. Senge

15.879 Seminar in System Dynamics Policy Analysis (A)

Prereq.: 15.872
G (1, 2)
3-0-6

Research seminar focusing on development of student projects to illuminate important aspects of policy analysis. 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, problems with use of leading and lagging indicators on policy inputs, economic policy, energy policy.
P. M. Senge, J. D. Sterman

Corporate Strategy and Policy

15.930 Strategic Management

Prereq.: —
G (1, 2)
2-0-4

15.931 Strategic Management (A)

Prereq.: 15.011, 15.311, 15.515
G (1, 2)
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.
15.930: *A. C. Hax, M. Horwitch, M. S. Scott Morton, N. Venkatraman*
15.931: *A. C. Hax*

15.932 Technology Strategy (A)

Prereq.: 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) (Revised Content)

Prereq.: 15.930 or 15.931
G (1)
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, M. Horwitch

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

15.935 Corporate Strategy and Structure (A)

Prereq.: 15.930 or 15.931
G (1)
3-0-6

Uses framework and methodology of 15.931 to analyze the strategic decisions facing industries and the firms within such industries. Combines lectures and student research presentations on such issues as determinants and consequences of industry structure, firm characteristics, innovation organization structures, and diversification. Information: M. Horwitch

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

15.937J Economics of Ocean Transportation (A)

(Same subject as 13.661J)
Prereq.: 14.120 or 15.012
G (2)
3-0-6

See description under subject 13.661J.
Z. S. Zannetos, H. N. Psaraftis

15.938 Strategy and Society (A) (New)

Prereq.: 15.930 or 15.931
G (1)
3-0-6

Examines the importance of societal context for strategic decision making at top and middle management levels. Issues presented: firm relations with local communities and local/national government, personnel flows among firms, interlocking board memberships, existence of managerial class, historical and cultural determinants of managerial ideologies, and the exercise of propaganda. Information: M. Horwitch

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

15.941 Managing the Development Effort (A)

Prereq.: 11.431 or 15.410 or 15.412 or 15.415
G (2)
3-0-6

Case studies presented by experienced real estate developers provide insights into managers' operational concerns such as scheduling, cost control, and motivation of personnel, as well as top management issues such as strategy, organization, and corporate culture. Demonstrates how effective management must integrate many skills including financing, leasing, and construction.
G. F. Bloom

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

15.961 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, enabling students to develop skill in careful listening and the art of asking questions. Restricted to Sloan School of Management graduate students. Information: J. D. C. Little.

15.978 Seminar in Management (A)

Prereq.: 15.511
G (1)
3-0-6

Studies 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

16 Aeronautics and Astronautics

16.UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in Aeronautics and Astronautics. For further information contact Departmental Coordinator:
E. A. Witmer

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. M. Greitzer, M. Martinez-Sanchez, J. E. McCune, H. Y. Wachman, E. A. Witmer

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 flow, rockets and turbomachinery; system dynamics and control, analog simulation of control system. Design and evaluation of an aircraft or spacecraft component.
A. L. Elias, E. M. Greitzer, A. R. Odoni, M. Martinez-Sanchez, J. E. McCune, H. Y. Wachman, E. A. Witmer

16.005 Introduction to Aerospace Engineering

Prereq.: —
U (2)
3-1-5

Presents 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 which each student designs. Recommended for freshmen.
N. D. Ham, D. L. Akin, J. Dugundji

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, performace, subsonic flow. Turbulence, separation and stall.
J. E. McCune

16.025 Numerical Fluid Dynamics (A)

Prereq.: 16.02 or 16.06, *18.075*
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. Potential, Euler, and Navier-Stokes equations in general nonorthogonal, curvilinear coordinates using finite-difference, finite volume 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
G (1)
4-0-8

Prepares students for graduate study in fluid mechanics and aerodynamics, and some of its applications in science and engineering. Discusses the basic concepts of continuous fluid mechanics, shows 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

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 in viscous compressible heat-conducting fluids as an approximation to the solution of exact equations of motion of fluids. Influence of various dimensionless parameters on laminar and turbulent aerodynamic flows and transition. Computational methods used for aerodynamic predictions including viscous-inviscid interactions.
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 not having 16.041.
J. F. Louis

16.044J Turbulence and Random Processes in Fluid Mechanics (A)

(Same subject as 12.865J)
Prereq.: 1.612 or 2.20 or *16.035* or 18.350
G (1)
3-0-9

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, J. H. Haritonidis

16.051 Gas Dynamics (A)

Prereq.: 16.035
G (2)
3-0-9

Fundamental concepts and modeling for perfect gas subsonic, mixed, and supersonic flows. Approximate (small disturbance, potential) and numerical (finite difference, characteristics, integral) methods. Waves, discontinuities, similarity for two-dimensional fields. Application to wings, bodies, test facilities. Introduction to viscous and real gas coupling influences.
J. R. Baron

16.052 Real Gas Dynamics (A)

Prereq.: 16.035
G (1) **Not to be offered 1987-88**
3-0-9

Dynamics of a real gas. Translational, chemical, and radiative nonequilibrium and equilibrium limit gas processes. Relaxation coupling with fluid dynamics for high temperature and rarefied conditions. Wave propagation, dispersion, similarity, shock phenomena, surface reaction coupling. Application to high-speed and space transfer vehicles, test facilities, and gas dynamic lasers. Alternate years.
J. R. Baron

16.055 Unsteady Fluid Mechanics (A)

Prereq.: 16.035
G (1) **Next offered 1987-88**
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 1987-88**
3-0-6

Develops understanding of basic phenomena underlying the physics of both unseparated and separated flows. Based upon recent experimental, theoretical, and CFD results. Initially, separation and reattachment of steady, two-dimensional laminar and turbulent boundary layers discussed. Their effect on the aerodynamic characteristics demonstrated. The literature of three-dimensional separated flows discussed critically. The effects of these nonlinearities upon the aircraft flight mechanics treated through trajectory analysis. Alternate years.
M. B. Giles

16.06 Molecular Gas Dynamics of Space and Reentry

Prereq.: 16.004 or 2.20 or 1.05
U (1)
4-0-8

Entry trajectories; dynamic and thermal loads on reentry vehicle. Molecular and transition flows. Introduction to kinetic theory of gases. Mass, momentum, and energy exchange on surfaces. Gas-surface interactions. Application to performance of space vehicles.
L. Trilling, H. Y. Wachman

16.065 Spacecraft-Environmental Interaction (A) (New)

Prereq.: 16.55
G (2)
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; $\underline{V} \times \underline{B}$ 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.
D. E. Hastings, H. Y. Wachman

16.07 Aerodynamics of Wings and Bodies (A)

Prereq.: 16.035, 18.075
G (2) **Next offered 1987-88**
3-0-9

Aerodynamic loading on wings and bodies. Lift versus 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

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

16.082J Flow Noise (A)

(Same subject as 2.065J, 13.84J)
Prereq.: 16.02 or 2.20, 16.081J
G (1) **Next offered 1987-88**
3-0-9

See description under subject 13.84J.
P. Leehey

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

16.20 Structural Mechanics

Prereq.: 16.004 or 2.01
U (1, 2)
5-0-7

Applies solid mechanics to analyzing 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.
E. F. Crawley, P. A. Lagace

16.21 Plates, Stability, and Thermoelasticity (A)

Prereq.: 16.20
G (2) **Next offered 1987-88**
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.
E. A. Witmer

16.22 Shell Structures (A)

Prereq.: 16.20
G (1) **Next offered 1987-88**
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

16.24 Plasticity, Viscoelasticity, and Creep (A)

Prereq.: 16.20
G (2) **Not to be offered 1987-88**
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. Consult advisor.
T. H. H. Pian

16.251 Structural Design for Longevity (A)

Prereq.: 16.20
G (1) **Not to be offered 1987-88**
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, P. A. Lagace

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.
J. E. Meyer, O. Buyukozturk

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) **Next offered 1987-88**
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.
J. W. Mar

16.293 Advanced Topics in Filamentary Composite Materials (A)

Prereq.: 16.292
G (1) **Next offered 1987-88**
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)
3-0-9

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.: 16.311 or 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.
B. K. Walker

16.321 Fault-Tolerant Control Systems (A)

Prereq.: 16.37
G (2)
3-0-9

The design and analysis of control systems which 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.
B. K. Walker, 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

16.341J Multivariable Control Systems I (A)

(Same subject as 2.154J, 6.233J, 10.28J, 13.47J)
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, B. K. Walker

16.342J Multivariable Control Systems II (A)

(Same subject as 2.155J, 6.234J, 10.29J, 13.48J)
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 1987-88**
3-0-9

See description under subject 6.532J.
C. M. Oman, 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.
S. R. Bussolari, 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, J. M. Tiech

16.36 Flight Simulation (A)

Prereq.: 18.03, 16.30 or 6.003 or 2.14
G (1)
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.
R. V. Kenyon, L. R. Young, A. L. Elias

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

Stochastic processes: mean square calculus, Wiener process, white noise, Gaussian processes, Markov processes, Ito stochastic calculus, Kolmogorov's equations. Linear filtering and smoothing theory: Kalman filter, optimal smoother, filter stability, steady state properties, sensitivity to model errors. Application of linear filter theory: extended Kalman filter, filter divergence, adaptive noise estimation, numerical considerations, square-root formulations. Gaussian second-order filter. Optimal control of stochastic linear systems: separation theorem.
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); Dead-Beat 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) **Next offered 1987-88**
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, 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)
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

16.42 Inertial Engineering II (A)

Prereq.: 16.41
G (2) **Not to be offered 1987-88**
3-0-9

Continues system design concepts presented in Inertial Engineering I. Error analysis of a local geographic coordinate system and extension to the general case of six other configurations. Role of geodesy and gravimetry in system design. Limitation of Kalman Filtering. Radio inertial hybrid system design. Seminars held by staff members of the Charles Stark Draper Laboratory on topics chosen primarily by the class.
W. R. Markey

16.46 Astrodynamics I (A)

Prereq.: 18.03
G (1)
3-1-8

Fundamentals of astrodynamics; two-body and n-body approximate and precision orbit determination. Fundamentals of space vehicle navigation emphasizing self-contained methods: statistical error analysis. Topics: universal orbital variables, recursive algorithms, variation of parameters, state space methods, maximum likelihood estimates, numerical integration, optimum measurement strategies, correlated measurement errors. 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 the two-body orbital boundary value problem with applications to space vehicle guidance for both powered flight and mid-course maneuvers. Topics: Lambert's problem and methods of solution, one-way and round-trip orbit determination to the moon and planets, orbital adjustment and transfer, linearized and explicit techniques for fixed and variable time of arrival guidance, velocity to be gained methods, 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.
M. Martinez-Sanchez

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, D. E. Hastings, D. Jordan

16.541 Aircraft Turbine Engines (A)

Prereq.: 16.54
G (2)
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.
J. F. Louis

16.543 Internal Flows in Turbomachines (A)

Prereq.: 16.035 or 2.25
G (2) **Not to be offered 1987-88**
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

16.55 Ionized Gases (A)

Prereq.: 8.211
G (1) **Not to be offered 1987-88**
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) **Not to be offered 1987-88**
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, non-equilibrium electronic heating, viscous effects, nonuniformities, time-dependent MHD performance. Plasma generators, thrusters, circuit breakers, and MHD generators.
J. F. Louis

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.
E. A. Witmer

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.
E. A. Witmer

16.61 Microcomputer Laboratory

Prereq.: 6.071 or 6.002; 2.10
U (1, 2)
2-8-2

Laboratory 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.
W. E. Vander Velde, W. M. Hollister, 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.
S. R. Hall, M. Drela

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.
S. R. Hall, M. Drela

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 assisted 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 1987-88**
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.
A. H. Epstein

16.671J Invention

(Same subject as 2.941J, 13.77J)
Prereq.: —
G (1)
3-0-6

See description under subject 2.941J.
W. R. Markey, D. G. Jansson, 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.
D. G. Jansson

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)
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.
A. L. Elias, R. W. Simpson

16.74 Air Transportation Economics (A)

Prereq.: 14.001
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, TPP 43J)
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.: 1.143 or 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)
3-0-6

See description under subject 1.231J.
A. R. Odoni, R. de Neufville

16.783J Engineering Policy Thesis Seminar (A)

(Same subject as 1.980J, TPP 13J)
Prereq.: Thesis Registration
G (1, 2)
2-0-1

See description under subject TPP 13J.
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)
3-0-9

School-Wide Elective Subject. Description given at end of this chapter on SWE page.
J. D. Nyhart

16.794 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2)
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 (2)
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)
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)
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.
D. L. Akin

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, etc., are 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.
M. Martinez-Sanchez, D. L. Akin, J. Dugundji

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) (New)

Prereq.: 6.071, 8.03
G (1)
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.
R. J. Hansman

16.87 VTOL Aircraft (A)

Prereq.: 16.02
G (1) **Next offered 1987-88**
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) (New)

Prereq.: 16.02
G (1) **Not to be offered 1987-88**
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. Consult advisor.
A. H. von Flotow

16.92 Advanced Aeroelasticity (A)

Prereq.: 16.004, 16.91
G (2) **Next offered 1987-88**
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.
E. F. Crawley, A. H. Von Flotow

16.93 Dynamics of Space Structures (A)

Prereq.: 16.91, 16.311 or 16.341J
G (1) **Not to be offered 1987-88**
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, J. Dugundji

16.94 Advanced Structural Dynamics (A)

Prereq.: 16.91
G (2) **Not to be offered 1987-88**
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)
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)
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.
R. K. Lester, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

16.995 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

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

Political Philosophy/Social Theory

17.103 Socialism

Prereq.: —
U (2) HUM-D
3-0-6

Studies the Socialist movement, ideas, and politics from the Industrial Revolution to the present. Explores history and theories of Socialism in Europe, Russia, USA. Topics: Utopian Socialists, Marx, Lenin, Stalinism, Social Democracy, Euro-Communism, and Socialism in the US.
S. Berger

17.104J Philosophies of Social Science (A)

(Same subject as 24.625J)
Prereq.: Permission of Instructor
G (2)
3-0-9

This subject 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. Literatures on democratization and international conflict provide the points of reference for discussion.
J. Cohen

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 Hobbes' *Leviathan*, Rousseau's *Social Contract*, and Hegel's *Philosophy of Right*. Graduate students are expected to pursue the subject at greater depth through reading and individual research. 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, St. Thomas, Machiavelli, and Luther.
B. H. Smith

17.110 New Currents in Social Theory (A)

Prereq.: —
G (1) **Next offered 1987-88**
3-0-9

Focus is on current efforts to formulate general theories of social transformation. The classical starting point: Marx and Weber. Difficulties with their views, and the search for alternatives. Neo-Marxism and related theories (Offe, Habermas); game theory and the "micro foundations" of society (Elster, Przeworski); "contextual" theories (Foucault, Rorty, Unger). Knowledge as a social product, society as a historical creation.
C. F. Sabel

17.113J Classics in Political Philosophy

(Same subject as 24.09J)
Prereq.: —
U (2) HUM-D
3-0-6

See description under subject 24.09J.
J. Cohen

Political Economy

17.154J Politics of Industrialization (A)

(Same subject as STS 510J)
Prereq: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-9

Focuses on the way the pace and direction of economic development depend on 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)
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

17.158 Political Economy of West Europe (A)

Prereq.: 17.534 or 17.156J
G (2)
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

17.164 Labor and Politics (A)

Prereq.: —
G (2) **Next offered 1987-88**
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 575J)
Prereq.: 17.156J
G (2)
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) **Next offered 1987-88**
3-0-9

17.168 Political Economy of Asia (A)

Prereq.: —
G (1) **Next offered 1987-88**
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, M. Weiner

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 multi-ethnic 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

17.172 Political Economy of the Middle East (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Focuses on economic and political transformations in the Middle East since World War II. The effects of the decolonization process in conjunction with efforts at institutional development provide the context for evaluating development strategies, changes in resource availability, and alternative paths to growth and change. A principal emphasis on competing strategies for change and modernization, and attendant political and economic consequences. Advanced undergraduates with permission of instructor.
N. Choucri

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) 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.
M. Lipsky, G. T. Marx

17.202 Theories of Public Policy (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Analyzes political issues involved in the conduct of policy analysis. Topics: criteria for government intervention (e.g., efficiency, equity, security, liberty, community); alternative methods of government intervention (market and incentive policies, standard-setting, creation of legal rights and duties, information-based strategies); philosophical assumptions (e.g., statistical indicators, cost-benefit analysis, risk analysis, microeconomic models). Students apply the theoretical issues to a policy topic of their choice. Consult Department headquarters.

17.203 Evaluation Research Laboratory

Prereq.: —
U (1) LAB
3-5-4

Introduces field of public policy evaluation. Acquaints student with the concepts and methods of evaluation research and aids the student in developing skills used in conducting evaluation studies. Topics: the concept of interventionary public policy programs, research designs for evaluating public policies, alternative analytic methodologies (quantitative and qualitative), and the politics, problems, and policy utilization of evaluative studies. Carries out individual evaluation projects as part of subject. May *not* count toward Humanities Requirement.
P. H. Lemieux

17.213 Regulation

Prereq.: —
U (2)
3-0-6

17.214 Regulation (A)

Prereq.: Permission of Instructor
G (2)
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.
D. Metlay

17.220J The Policy-Making Process (A)

(Same subject as TPP 22J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Analyzes the political process by which issues arise, and public policies are formulated, contested, determined, implemented, and evaluated. Treats the role of mass activity (including protest politics), professional expertise, elites, 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

17.227 Comparative Health Systems

Prereq.: —
U (1)
3-0-6

17.228J Comparative Health Systems (A)

(Same subject as 15.141J)
Prereq.: Permission of Instructor
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. Meets with 17.227.
H. M. Sapolsky, S. N. Finkelstein

17.235 Theories of Organizations

Prereq.: —
U (1)
3-0-9

17.236 Theories of Organizations (A)

Prereq.: Permission of Instructor
G (1)
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.
D. Metlay

American Politics

17.241 Introduction to the American Political Process

Prereq.: —
U (1, 2) 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 Presidency, 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.
L. Menand, C. Stewart

17.243 American Politics and Social Change

Prereq.: —
U (2) HUM-D
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)
(New)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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 (1)
3-0-9

An interpretation of constitutional rights, processes, and concepts of limited government in light of Supreme Court decisions and of Executive and legislative initiatives.
L. Menand

17.247 National Security and Democratic Values
(New)

Prereq.: 17.241, 17.243 or 17.245
U (2)
3-0-9

The growth of national security concerns poses important challenges and problems for individual freedom and democratic processes. An examination of this phenomenon and congressional and presidential initiatives to deal with these perceived problems. Intelligence agencies, loyalty-security clearances, secrecy and classifications, espionage, freedom of press, of travel, of scientific exchanges, and defense spending examined.
L. Menand

17.249 Electoral Politics in the US

Prereq.: 17.241
U (2) **Next Offered 1987-88**
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) (New)

Prereq.: Permission of Instructor
G (1)
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. Older views, such as Huntington's concept of the "Tudor Polity," are also treated. Open to undergraduates by permission of the instructor.
R. M. Vallelly

17.251 Congress and the American Political System

Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

17.252 Congress and the American Political System (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-9

Focuses both on 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

17.255 Politics, TV, and the News

Prereq.: —
U (1)
3-0-6

The role of television, considered by some the most powerful mass medium in shaping American public attitudes. Focus on TV but newspapers and magazines also discussed. Topics: political coverage of elections and policies; news "management" by both government and media; Presidential access to media; coverage of foreign news; science and technology; economics. Lectures and recitations combine "live" and taped appearances of guests and presentation of issues.
E. Diamond

17.257J American Society: Values, Institutions, and Variety

(Same subject as 11.006J)
Prereq.: —
U (1) HUM-D
3-0-9

See description under subject 11.006J.
G. T. Marx

17.258 Politics of Race and Ethnicity in America (A) (New)

Prereq.: Permission of Instructor
G (2)
3-0-9

17.259 Politics of Race and Ethnicity in America (New)

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 (2)
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 (New)

Prereq.: —
U (2)
3-0-9

17.262 Congress and the Policy Process (A) (New)

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 (1) **Next offered 1987-88**
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 (New)

Prereq.: —
U (1)
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 (New)

Prereq.: —
U (1)
3-0-9

The US President as constitutional executive, as sharer of governing authority with Congress and the courts, as party leader, as chief manager of exective agencies, as foreign policy leader, as focus for national political, economic, and social aspirations. Is the modern presidency compatible with democratic traditions and the traditional rule of law?
L. Menand

17.270 Evolution of American Politics (A)

Prereq.: —
G (2)
3-0-9

17.271 Evolution of American Politics

Prereq.: 17.241
U (2)
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, however, 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.
W. D. Burnham

See also 17.702, 17.704, 17.707, 17.720.

Urban Politics and Public Policy

17.281 Urban Politics

Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

Analyzes current American urban political issues in terms of their historical and sociological bases, theoretical significance, and relationship to broader American politics. Deals with concepts involving power structures, ethnicity, law, justice, public participation, and public administration. Specific concerns include education, housing, police, transportation, welfare, and other dimensions of public policy.
M. Lipsky

17.286 Seminar in Urban Politics (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-9

Examines current issues in urban politics, and alternative perspectives for analyzing them. Includes: machine politics, the legacy of the reform movement, community action and citizen participation, decentralization, metropolitanization, public service policy and delivery, and the fiscal crisis of the city. Considers the utility of pluralist and neo-Marxist frameworks in understanding American urban political development and public policy. Open to undergraduates with permission of instructor.
M. Lipsky

17.296 The Organization of Public Policy (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Analyzes the political and policy implications of delivering policy through public, quasi-public, 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

Science, Technology, and Policy

17.301 Science, Technology, and Politics

Prereq.: —
U (1)
3-0-6

17.302 Science, Technology, and Politics (A)

Prereq.: —
G (1)
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.
D. Metlay

17.306J Special Topics in Science, Technology, and Public Policy (A) (New)

(Same subject as STS 460J)
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.
E. B. Skolnikoff, H. M. Sapolsky, C. Kaysen, P. S. Buck

17.322 Seminar in Systematic Policy Analysis and Technology Assessment (A)

Prereq.: 14.01, 14.02
G (2) **Next offered 1987-88**
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
G (1) **Not to be offered 1987-88**
3-0-9

Explores the roles of science and technology and their impact in the international 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, North/South relations, 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 207J)
Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
2-0-10

See description under subject STS 207J.
P. Buck

International Relations/Arms Control and Defense Studies

International Relations and Foreign Policy

17.401 Just Wars, Total Wars, and Nuclear Wars

Prereq.: —
U (2) HUM-D **Next offered 1987-88**
4-0-8

The contemporary debate about nuclear war and international security put in the context of historical, political, and moral arguments about just and unjust wars (including wars of religion and crusades), total wars (those without limits on objectives, arenas, and weaponry) and totalitarian states (those unlimited in the jurisdiction and political means of their power exercisers). Documentary, video, and computerized exercises supplement class discussions. Consult Department headquarters.

17.403 American Foreign Policy in a Changing World

Prereq.: —
U (1) 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 (2)
3-0-6

17.406 Seminar in Middle Eastern Politics (A)

Prereq.: Permission of Instructor
G (2)
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, and their interaction with the energy crisis. 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.: 17.401 or 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.
N. Choucri

17.422 International Political Economy (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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, among others. 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

17.428 US Foreign Policy — Past, Present, Future (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
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) **Not to be offered 1987-88**
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 Dept., and System weaknesses. Organizing for interdependence. 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 (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-9

Special topics concerning African international relations, including US relations with Southern Africa, African international organizations, and African participation in multilateral organizations. Undergraduate students only with permission of instructor.
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) **Not to be offered 1987-88**
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 (1) **Not to be offered 1987-88**
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.
R. K. Lester, P. Morrison, G. W. Rathjens, E. Rothschild, 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

17.469 Military Forces and Foreign Policy

Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

17.470 Military Forces and Foreign Policy (A)

Prereq.: —
G (1) **Next offered 1987-88**
3-0-9

A comparative examination of US and Soviet defense policies, foreign policies, and the use of their military forces in the post-war 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 (2) **Next offered 1987-88**
3-0-9

17.473 American Security in the Nuclear Age

Prereq.: —
U (2) **Next offered 1987-88**
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

17.482 General Purpose Forces (A)

Prereq.: 17.480
G (2) **Next offered 1987-88**
3-0-6

Introduces the planning of the nuclear and non-nuclear general purpose forces. Emphasizes methods used to analyze the cost and effectiveness of alternative land, air, and naval capabilities in achieving deterrence and stability. Attention to the ability of NATO to deter the Warsaw Pact. Open to undergraduates by permission of instructor only. Consult S. M. Meyer.

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 (2)
3-0-6

17.488 Quantitative Approaches to Defense Problems (A)

Prereq.: 17.486, 17.465 or 17.842
G (2)
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 1987-88**
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 which 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

Considers issues in the military and political security of Europe in the post-1945 period, decline of the cold war, consolidation of status quo; the German question and Ostpolitik; MBFR negotiations; role of new weapons systems (SS-20, Pershing 2, Cruise Missile); differing W. European and US estimates of the USSR and their policy results; the energy crisis and US-W. European differences on Middle Eastern policy.
W. E. Griffith

See also 17.301, 17.302, 17.328, 17.401, 17.403, 17.405, 17.406, 17.407, 17.420, 17.428, 17.430, 17.587, 17.604.

Comparative Politics/Political Development/Communist Studies

Theories and Research Methods

17.501 The Quest for Equality and Development in Third World Countries

Prereq.: —
U (1) HUM-D
3-0-9

Examines value aspects of and policy choices in attempts to achieve economic growth with social justice and popular democracy in underdeveloped countries. Examines the basic ideological and structural dynamics of Third World societies, including racism, nationalism, industrialism, capitalism, socialism, environmentalism, and religious revivalism. Considers tensions between growth and equality, between domestic and international needs, and between political and economic interests. Attention to local values and historical context.
W. R. Johnson

17.505 African International Relations

Prereq.: —
U (2) **Next offered 1987-88**
3-0-9

Comparative analysis of the foreign relations and policies of African states, including their relations with the US, and their relations with and participation in international, regional, and worldwide organizations.
W. R. Johnson

17.512 Theories of Political Development (A)

Prereq.: Permission of Instructor
G (1)
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 1987-88**
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) **Next offered 1987-88**
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)
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, and the GDR. Open to qualified undergraduates.
W. E. Griffith

17.534 Domestic Politics of Western Europe (A)

Prereq.: Permission of Instructor
G (1)
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

17.536 Research Seminar in Comparative Politics: Western Europe (A)

Prereq.: 17.534
G (2) **Next offered 1987-88**
3-0-6

For students planning research in Western European countries. Discussion of current work in the field. Training in the use of European primary source materials and in research methods applicable to European problems. Presentation of students' own research projects.
S. Berger

17.539 Politics and Policy in Contemporary Japan

Prereq.: —
U (1)
3-0-6

17.540 Politics and Policy in Contemporary Japan (A)

Prereq.: Permission of Instructor
G (1)
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 the development of less idiosyncratic approaches to the study of Japan. Graduate students are expected to pursue the subject at greater depth through reading and individual research. 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
3-0-9

Introductory survey of Latin American politics in comparative perspective. Theoretical focus on socio-economic conditions of political change and on state formation since the conquest, with particular emphasis on the twentieth century. Special attention to selected cases (Argentina, Mexico, Cuba, Central America) and to the role of the US.
P. H. Smith

17.544 Comparative Politics of Latin America (A)

Prereq.: —
G (1)
3-0-9

Latin American politics in a comparative perspective. Theoretical focus on three contrasting models of development: modernization, dependency, and bureaucratic-authoritarianism. Case studies with different political systems and economic models since 1960, such as Chile, Brazil, Cuba, Colombia.
B. H. Smith

17.545 Political Change in South Asia: India, Pakistan, Bangladesh, and Afghanistan

Prereq.: —
U (2)
3-0-6

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)
3-0-6

17.548 Chinese Politics (A)

Prereq.: Permission of Instructor
G (2)
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

17.549 Political and Economic Development of Tropical Africa

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-9

Studies major facets and problems of economic and political development in tropical Africa. Introduces the history and political cultures of African peoples, states, and empires throughout history. Considers the impact of African culture and philosophy on modern politics. A general introduction to African Politics.
W. R. Johnson

17.551J The History of 20th-Century Africa: Nationalism and Nation Building

(Same subject as 21.451J)
Prereq.: —
U (2) HUM-D
3-0-9

17.552 Nationalism and Nation Building in 20th-Century Africa

Prereq.: Permission of Instructor
G (2)
3-0-9

See description under subject 21.451J. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.551J.
R. I. Rotberg

17.553J The History and Politics of the Third World through the Novel

(Same subject as 21.455J)
Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

See description under subject 21.455J.
R. I. Rotberg

17.556 Political and Institutional Changes in the Middle East (A) (New)

Prereq.: 17.406
G (1) **Next offered 1987-88**
3-0-9

Historical and contemporary analysis of community building and state formation in the region. Focuses on conflict systems generating political responses and institutional adaptation. Review of major ideological and social movements in the 20th century, as a basis for analyzing evolving relations between state, policy, and economy in the Middle East. Open to undergraduates with permission of instructor.
N. Choucri

17.558J Politics, Growth, and Development in the Middle East (A) (New)

(Same subject as 1.255J)
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, P. Khoury, F. Moavenzadeh, D. Lessard

17.560J Technology, Business, and Public Policy in the Middle East (A) (New)

(Same subject as 1.256J)
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, A. Adelman, F. Moavenzadeh D. Lessard

17.562J Modern Egypt and Iran: Islam and Politics in Historical Perspective (A) (New)

(Same subject as 21.484J)
Prereq.: —
G (2) HASS
3-0-9

See description under subject 21.484J. Open to undergraduates.
P. S. Khoury

17.564J Research Seminar in Imperialism and Colonialism

(Same subject as 21.457J)
Prereq.: Permission of Instructor
G (2)
3-0-6

See description under subject 21.457J.
R. I. Rotberg

17.574 Comparative African Politics: Crises in Southern Africa

Prereq.: Permission of Instructor
G (2)
3-0-6

Comparative analysis of political systems and problems of southern Africa. Attention to South Africa's revolution. Also discusses Nambia, Botswana, Angola, Mozambique, Zambia, Zimbabwe, and Zaire. Although seminar's primary focus is on the emergence of stable systems of governance in the southern tier of Africa, it examines the formulation of US foreign policy regarding the region. Undergraduates permitted with permission of instructor.
R. I. Rotberg

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. Considers major theoretical literature on development relevant to Africa.
W. R. Johnson

17.579 The Political Economy of Modernization in China

Prereq.: —
U (1)
3-0-6

17.580 The Political Economy of Modernization in China (A)

Prereq.: —
G (1)
3-0-9

Examination of the political economy of modernization in post-1949 China with emphasis on the post-Mao period. Analyzes the interaction of political and economic variables as they relate to such topics as foreign investment and technology transfer, research and education, economic management, foreign economic policy, and defense modernization. Course materials and lectures are drawn from primary and secondary literature dealing with prevailing modernization issues. Graduate students are expected to pursue the subject at greater depth through additional reading and individual research.
D. F. Simon

See also 17.406, 17.438.

17.584 Religion, Politics, and Social Change in Developing Countries (A)

Prereq.: —
G (2)
3-0-9

17.585 Religion, Politics, and Social Change in Developing Countries

Prereq.: —
U (2) HUM-D
3-0-6

Major issues of religion and politics in various developing countries. Focus on: 1)theories of religion's impact on social change, 2)differing church-state concepts in the major world religions, 3)religion as a progressive and reactionary political force, 4)religion under authoritarian governments. Case studies from Latin America, Africa, Middle East, and Asia. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.584.
B. H. Smith

17.586 The Military and Politics in Comparative Perspective (A)

Prereq.: —
G (2)
3-0-9

17.587 The Military and Politics in Comparative Perspective

Prereq.: —
U (2)
3-0-6

Political interests, resources and impact of the military in Western industrial nations, Communist societies and developing countries. Historical and theoretical treatment of: 1)contrasting models of civil-military relations; 2)conditions enhancing and eroding civilian control of the military; 3)impact of modern technology and social instability on the political role of the military; and 4)capabilities and consequences of the armed forces in managing government tasks. Graduate students are expected to pursue the subject at greater depth through reading and individual research. Meets with 17.586.
B. H. Smith

17.588 Field Seminar in Comparative Politics (A)

Prereq.: Permission of Instructor
G (2) **Not to be offered 1987-88**
Arr.

For advanced graduate students planning to offer General Examinations in the field of comparative politics. Assumes the student has a familiarity with a sampling of the major works in this field, but wishes opportunity to deepen and broaden that familiarity. No research papers required. Topics: political participation, interest groups, the intellectual history of the field, political culture, methodologies, political development, political economy, and public policy.
R. J. Samuels, Staff

17.590 Research Seminar on Latin American Politics

Prereq.: —
G (1)
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.
P. H. Smith

See also 17.168, 17.170, 17.172.

Communist Studies

17.602 Continuity and Change in Soviet Politics (A)

Prereq.: —
G (2)
3-0-9

17.603 Continuity and Change in Soviet Politics

Prereq.: —
U (2)
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 Soviet and Chinese Foreign Policy and the Communist World (A)

Prereq.: —
G (1) **Next offered 1987-88**
3-0-9

Reviews Soviet state and party relations with China and East Europe during the Stalin period and analyzes Sino-Soviet relations since 1953. Includes Soviet and Chinese dealings with East Europe, North Korea, North Vietnam, Cuba, and the Eurocommunist parties. Open to qualified undergraduates.
W. E. Griffith

17.606 The Politics of Communist States and Parties in Eastern and Western Europe (A)

Prereq.: —
G (2) **Next offered 1987-88**
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 1987-88**
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. 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) **Next offered 1987-88**
3-0-6

17.610 Seminar in the Historical and Political Evolution of the Soviet Union

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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 1987-88**
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 212J)
Prereq.: —
G (2)
3-0-9

See description under subject STS 212J.
L. R. Graham

17.616 Soviet Policy Toward the Third World

Prereq.: —
G (2) **Next offered 1987-88**
3-0-9

After a general survey of Soviet third world policy, focuses on Soviet policy in four regions: the Middle East, southern Africa, Central America and the Caribbean, and Indochina. Includes: Soviet arms supply, guerilla movements and terrorism, other leftist and revolutionary movements, and "proxies" (e.g., Cuban troops and advisers in Angola and the Caribbean). Open to qualified undergraduates.
W. E. Griffith

See also 17.490.

Political Communication/ Political Behavior

17.702 Political Behavior and American Politics (A)

Prereq.: —
G (1) **Next offered 1987-88**
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.
W. R. Neuman

17.704 Political Psychology and Behavior (A) (New)

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

17.707 Mass Communication and American Culture

Prereq.: —
U (2) HUM-D
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.
W. R. Neuman

17.720 Communication and Public Opinion (A)

Prereq.: —
G (2)
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

17.722 Social Impact of Communications Systems (A)

Prereq.: —
G (1) **Next offered 1987-88**
3-0-9

Compares communications systems of societies dominated by mass media (as our own) with both less developed and emerging new systems. Examines communications in developing countries. Open to qualified undergraduates. Consult Department headquarters.

17.726 Political Culture (A)

Prereq.: Permission of Instructor
G (2)
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

17.736 Reading Seminar in Communications Research (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Reading and discussion of special topics in communications research and policy analysis by arrangement with individual staff members. Consult: W. R. Neuman.

17.738 Communications Research Practicum (A) (New)

Prereq.: Permission of Instructor
G (1, 2)
3-6-3

Designed primarily for research assistants conducting studies of advanced communications technologies at the Media Laboratory's Audience Research facility.
W. R. Neuman

17.740 Telecommunications Technology and Policy (A)

Prereq.: —
G (1)
3-0-9

Basis in technology, law, and economics for public and private telecommunications networks. Regulation of common carriers such as AT&T, the Postal Service, and specialized carriers. Role of new technologies such as microwaves, satellites, integrated digital networks, computer communications, value-added services, and cable TV. Issues of competition, monopoly, and technical standards. Implications for the management of corporate telecommunicatons networks. Open to qualified undergraduates. Consult Department headquarters.

17.742J Mass Communications Technology and Policy (A)

(Same subject as 4.254J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Assesses the relationship between changing mass communications technologies and the policy issues of press freedom, content diversity, cross-media ownership, public access, copyright, and the deregulation movement. Examines the social impact of the emergence of printing and broadcasting and the effect of satellite technology, cable television, videodiscs, videotex, and other new media on the communications industry.
W. R. Neuman, A. Lippman

17.744 International Communications (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Includes the structure of the international telecommunications systems, the way in which agreements are reached through organizations such as the ITU and Intelsat, controversial issues about international broadcasting, orbit and spectrum allocations, and trans-border data networks. Examines telecommunications industry structure in Europe, Japan, Canada, USSR, and developing countries.
R. M. Tyler, C. M. Jonscher

17.748 Information and Communications Industries (A)

Prereq.: Permission of Instructor
G (1)
Arr.

Analyzes past developments and future strategies of industries providing information and communications systems and services including computing, telecommunications, office automation, database services, and new media. Reviews factors causing growth in information needs of the economy. Examines options for business strategy and policy in the information and communications industries.
C. M. Jonscher

See also 17.255, 17.257, 17.264, 17.814.

Polimetrics/Models and Methods

17.803 Debates and Arguments

Prereq.: —
U (2) **Next offered 1987-88**
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)
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 which illustrate sound use of such methods as well as their limitations.
D. Metlay, 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.
M. Weiner

17.818J Applied Social Research, Public Policy, and the Social Sciences

(Same subject as STS 440J)
Prereq.: —
G (1) **Next offered 1987-88**
3-0-9

Problems and possibilities in policy-oriented social research. Historical and contemporary case studies treat three questions: what does applied social research contribute to policy making; how scientific is it; and do the natural sciences offer useful models for the combining of theory, fact, and application in the social sciences?
P. Buck

17.842 Quantitative Research in Political Science and Public Policy (A)

Prereq.: Permission of Instructor
G (2)
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.
S. M. Meyer

17.846 Multivariate Political Analysis (A)

Prereq.: Permission of Instructor
G (1)
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.: Permission of Instructor
G (1) **Next offered 1987-88**
Arr.

Research seminar focuses on the communicative content of social-political interactions. Grammatical approaches to the modeling of social and political competence and performance reviewed as well as data analysis procedures for uncovering linguistic codes and messages. Discusses models from biological, linguistic, logical, semiotical, and artificial intelligence traditions. Examples drawn from small group, urban, national, and international contexts.
H. R. Alker, Jr.

17.850 Advanced Topics in Statistical Modeling (A)

Prereq.: 17.846
G (1) **Next offered 1987-88**
3-0-6

Focus 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, 17.488.

General

17.UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in Political Science in theoretical and applied research. For further information contact the Departmental Coordinator.
D. L. M. Blackmer

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

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.
D. L. M. Blackmer

17.913 Pre-thesis Reading Seminar

Prereq.: —
U (1, 2)
3-0-6

Intensive reading on topics of interest to students in preparation for senior thesis under guidance of thesis supervisor. A written paper required, forming a substantial part of the senior thesis.
D. L. M. Blackmer

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

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.
D. L. M. Blackmer

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

18 Mathematics

General Mathematics

18.UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in Mathematics. Permission required in advance to register for this subject. For further information consult the Departmental Coordinator.
D. A. Vogan, Staff

18.01 Calculus

Prereq.: —
U (1, 2)
5-0-7

Differentiation and integration of functions of one variable, with applications. Concept 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 some prior knowledge of calculus
U (1)
5-0-7

Reviews 18.01 material in five weeks. Infinite series. Taylor's formula. Probability. Vectors, vector-valued functions of one variable, space motion. Scalar functions of several variables, partial differentiation, gradient, approximation techniques. Information: D. A. Vogan

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

(18.001)
Prereq.: Assumes some prior knowledge of calculus
U (1)
5-0-7

Emphasizes the concepts and techniques of calculus relevant to science and technology. Mathematical formulation of problems and approximate methods of solution. Substantial review of limits and differentiation with discussion of some advanced methods. Intensive study of integration; perturbation and iteration procedures; stability; series; summation techniques; asymptotics; numerical analysis; vector algebra; special topics.
H. P. Greenspan

18.02 Calculus

Prereq.: 18.01 or 18.011 or 18.012 or 18.013
U (1, 2, S)
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' Theorem. Additional topics: linear algebra (term 1); infinite series (term 2).
Term 1: *H. Rogers, Jr.*
Term 2: *S. Helgason*

18.021 Calculus

Prereq.: 18.011
U (2)
5-0-7

Continues 18.011: calculus of several variables, with elementary linear algebra and applications. Vector fields, line integrals, exact differentials. Elementary linear algebra, Jacobians. Green's Theorem, surface integrals, Divergence Theorem, Stokes' Theorem. Permission of instructor required for those not having 18.011. Information: D. A. Vogan

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.
J. R. Munkres

18.023 Calculus with Applications

(18.002)
Prereq.: 18.013 or 18.01 or 18.011 or 18.012
U (1, 2)
5-0-7

Continues 18.013. Presents the concepts and techniques of calculus relevant to science. 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 & Gauss, conservation laws, fluid motion.
D. J. Benney

18.03 Differential Equations

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
U (1, 2, S) SD
4-0-8

Examples of initial value problems in science and engineering associated with single equations and with 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: *F. Morgan, Staff*
Term 2: *G-C. Rota, Staff*

18.04 Complex Variables with Applications

Prereq.: 18.03
U (1, 2, S)
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: *A. Toomre*
Term 2: *L. N. Trefethen*

18.05 Introduction to Probability and Statistics (Revised Unit)

Prereq.: 18.001 or 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. Non-parametric methods. Normal distribution methods. Regression. Elements of decision theory.
Term 1: *R. M. Dudley*
Term 2: *N. Lange*

18.057 Computer Data Analysis Laboratory (A except XVIII)

Prereq.: 18.05 or 15.061
U (2) G (2) **Next offered 1987-88**
3-2-7

Methods of data analysis using computers and microcomputers. Introduction to and practice with the most frequently encountered statistical software systems including MINITAB, SAS, and BMDP. Statistical analyses using Project Athena microcomputers. Emphasizes intuitive bases of common statistical procedures and the use of interactive computer packages to analyze a wide variety of data sets. No previous programming experience necessary. Some statistics background necessary. Information: R. M. Dudley

18.06 Linear Algebra

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
U (1, 2, S) SD
3-0-9

Basic subject on matrix theory and linear algebra, emphasizing topics useful in other disciplines: 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.
G. Strang, Staff

18.063 Introduction to Algebraic Systems

Prereq.: 18.02 or 18.002 or 18.021 or 18.022
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. Information: D. A. Vogan

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. A. Vogan

18.085 Mathematical Methods for Engineers I (A)

Prereq.: 18.03
G (1, 2)
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, transforms, convolution, complex variables, finite difference methods for partial differential equations.
G. Strang, Staff

18.086 Mathematical Methods for Engineers II (A)

Prereq.: 18.03
G (1, 2)
3-0-9

Scientific computing: Fast Fourier Transform, finite differences and stability, finite elements, spectral method, numerical linear algebra. 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 (including Karmarkar's method), duality, nonlinear problems.
Term: 1 *N. Trefethen*
Term: 2 *A. Toomre*

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. A. Vogan

18.093 Tutoring in Mathematics

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
U (1, 2)
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. A. Vogan

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 is for students with more mathematical maturity; places greater emphasis on point-set topology. Information: D. A. Vogan

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' theorem.
A. Sanchez-Calle

18.102 Analysis II (A except XVIII)

Prereq.: 18.100
G (2) **Not to be offered 1987-88**
3-0-9

Continues 18.100, in the direction of modern integration theory and its applications. Lebesgue integration in Euclidean space. Its applications to Fourier analysis, including the Riesz-Fischer theorem. Brief introduction to functional analysis. Information: D. A. Vogan

18.103 Fourier Analysis — Theory and Applications (A except XVIII)

Prereq.: 18.100
G (1) **Next offered 1987-88**
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. 18.103 is an alternative to 18.102; the material is somewhat similar, but it differs from 18.102 in that a heavy stress is paid to applications, particularly applications in probability theory.
V. W. Guillemin

18.104 Seminar in Analysis

Prereq.: 18.100
U (1)
3-0-9

Seminars for mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Students report on and discuss topics taken from current journals or from texts not regularly used in other mathematics subjects. Certain topics may require an additional prerequisite.
D. W. Stroock

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.
H. M. Stark

18.116 Topics in Complex Variables (A)

Prereq.: 18.115
G (2) **Next offered 1987-88**
3-0-9

Topics vary from year to year: may be repeated for credit. Topics in the past: classical theory of automorphic functions; modular forms; Riemann surfaces; analytic number theory. Emphasizes as elementary an exposition as possible. Information: R. B. Melrose

18.117 Topics in Several Complex Variables (A)

Prereq.: 18.115, 18.125
G (1) **Next offered 1987-88**
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) (Revised Content)

Prereq.: 18.100
G (1)
3-0-9

Lebesgue integration with emphasis on 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

18.128 Geometric Measure Theory (A)

Prereq.: 18.125
G (2) **Next offered 1987-88**
3-0-9

Hausdorff measure, rectifiable sets, structure theory, integral currents, compactness theorem. Applications to minimal surfaces, existence and regularity. Reports and discussions by students.
F. Morgan

18.135 Geometric Analysis (A)

Prereq.: 18.125
G (2) **Next offered 1987-88**
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

18.137 Harmonic Analysis (A)

Prereq.: 18.155
G (2) **Next offered 1987-88**
3-0-9

Applications of Fourier analysis to partial differential equations. Estimates in L^p, BMO, and other spaces for singular integral operators and Fourier multipliers. Applications to existence and uniqueness of solutions of nonlinear partial differential equations and linear partial differential equations with borderline smoothness. Exotic pseudodifferential operators.
D. S. Jerison

18.152 Introduction to Differential Equations (New)

Prereq.: 18.100
U (1)
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.
S. Helgason

18.156 Introduction to Microlocal Analysis (A)

Prereq.: 18.155, 18.965
G (1) **Not to be offered 1987-88**
3-0-9

Examines singularities of distributions. Distributions singular across a submanifold, singular points of ordinary differential equations, non-characteristic 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 1987-88**
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) **Not to be offered 1987-88**
3-0-9

Content varies from year to year; may be repeated for credit. Topics: Nonlinear hyperbolic equations, propagation of singularities, and interaction of nonlinear waves. Information: R. B. Melrose

18.159 Nonlinear Functional Analysis (A)

Prereq.: 18.103 or 18.125
G (1) **Next offered 1987-88**
3-0-9

Introduction to general nonlinear functional analysis (Sobolev spaces, convex analysis, Mountain pass lemma, etc.) with applications to geometry and physics: 1)Variational problems involving lack of compactness; Yamabe's and Rellich's conjectures; Large harmonic maps. 2)Nonlinear elliptic and parabolic equations; isolated singularities; the Thomas-Fermi equation. 3)Periodic solutions for nonlinear wave equations. Information: R. B. Melrose

18.168 Analysis on Lie Groups and Homogeneous Spaces (A)

Prereq.: 18.755
G (2) **Next offered 1987-88**
3-0-9

Invariant measures and abstract integral geometry illustrated by examples. Invariant differential operators and geometric transformations of these, like projections, radial parts and transversal parts. Global and local solvability, integral formulas for eigenfunctions and irreducibility questions for eigenspace representations.
S. Helgason

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.
R. M. Dudley

18.177 Stochastic Processes (A)

Prereq.: 18.175
G (1, 2) **Next offered 1987-88**
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. Information: R. M. Dudley

18.199 Graduate Analysis Seminar (A)

Prereq.: Permission of Instructor
G (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)
(New)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Topics vary from year to year; may be repeated for credit. Topic for 1986-87: String theory for mathematicians.
I. M. Singer

18.255 Mathematical Theory of Quantum Fields (A)

Prereq.: 18.101 or 8.022
G (2) **Next offered 1987-88**
3-0-9

Free quantum fields; their particle and functional integration representations. Unitary implementability of canonical transformations, C*-algebraic methods. Quantization of invariant wave equations in Minkowski and alternative space-times. Nonlinear local functions of fields; Wick products. Introduction to constructive quantum field theory.
I. E. Segal

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. Formulations are rigorous, but details and proofs are largely omitted. Quantum mechanics and field theory, general concepts of space-time, global theory of nonlinear wave equations and their interrelations. For mathematicians or physicists of the maturity normally represented by graduate standing.
I. E. Segal

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.
R. P. Stanley

18.295 General Relativity (A)

Prereq.: 18.06, 8.06, 8.312
G (2) **Next offered 1987-88**
3-0-9

The physical background and mathematical formulation of the general theory of relativity. Includes tensor calculus, differential forms, and Riemannian geometry
N. P. Warner

Applied Mathematics

18.301 Introduction to Physical Mathematics I

Prereq.: 18.03
U (1)
3-0-9

Interdependence of mathematics and scientific problems, examples; deterministic and random processes; particle mechanics and differential equations, Brownian motion and random walk; Fourier analysis; tensors; partial differential equations of mathematical physics and continuum mechanics. Knowledge of 18.04 recommended.
C. C. Lin

18.302 Introduction to Physical Mathematics II

Prereq.: 18.301, 18.04 or 18.284
U (2)
3-0-9

Partial differential equations of mathematical physics, classification and solution of boundary-value problems, method of separation of variables. Sturm-Liouville problems, Fourier integrals, integral transforms. Bessel functions and other special functions. Applications of calculus of variations. A knowledge of complex variables desirable but not essential.
C. F. Pearson

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: *A. Toomre*
18.306: *S. L. Zaleski*

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.
H. Cheng

18.308 Wave Motion (A) (Revised Content)

Prereq.: Permission of Instructor
G (2)
3-0-9

Combustion theory and hyperbolic systems. Nonlinear waves in reacting and compressible media: characteristics, shocks, shock reflections and interactions, nonlinear resonant interactions of acoustical and entropy/vorticity waves. Structure and stability of detonation waves and flames, bifurcation phenomena: spinning and "galloping" detonations, Mach Stems, cellular flames. High-frequency waves in reacting compressible media, hot spots, initiation and transition phenomena. May be repeated for credit by permission of instructor.
R. R. Rosales

18.310 Principles of Applied Mathematics

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
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, but connection with discrete mathematical approach also stressed: random walk, diffusion, waves, instabilities, characteristics and first order partial differential equations, with applications to traffic problems, fluid flow, and other problems in classical mathematical physics.
R. R. Rosales

18.313 Probability

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
U (2) SD
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.
G-C. Rota

18.314 Applied Combinatorial Analysis

Prereq.: 18.001 or 18.01 or 18.011 or 18.012 or 18.013
U (1)
3-0-9

Applications of combinatorial methods to practical problem solving. Emphasizes problems involving discrete optimization. Techniques from graph theory, matching theory, network flows. Other topics include enumeration, sorting and coding.
M. D. Haiman

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.
G-C. Rota

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 1986-87: Symmetric functions with applications to representation theory.
R. P. Stanley

18.325 Topics in Applied Mathematics (A)

Prereq.: Permission of Instructor
G (1, 2)
3-0-9

Term 1: Linear and nonlinear waves and instability theories. Emphasis on topics of current research interest. Term 2: Dynamical systems, strange attractors, and chaos. Normal forms. Lorenz, Van der Pol equations. Hyperbolic invariant sets, horseshoes, stable and unstable manifolds. Measure and ergodic theory. Entropy, Liapunov exponents. Applications to maps, nonlinear differential equations.
Term 1: *D. J. Benney*
Term 2: *S. L. Zaleski*

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.
M. Trummer

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: numerical linear algebra, including solution of linear systems of equations, least-squares computations, eigenvalue computations, and iterative methods (classical, conjugate gradient, and Lanczos). 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: *M. Trummer*
18.336: *L. N. Trefethen*

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: *D. J. Benney*
18.355: *C. F. Pearson*

18.356 Rotating Fluids (A)

Prereq.: 18.305, 18.354
G (2)
3-0-9

General theory of rotating fluids; transient flows; effects of viscosity, stratification, and compressibility; wave motion; nonlinear interactions; stability theory and the advent of aperiodicity; application to laboratory, astrophysical, and geophysical problems.
W. V. R. Malkus

18.357 Seminar in Fluid Dynamics (A)

Prereq.: 18.354
G (1)
3-0-9

Frontiers of nonlinear stability theory. Bifurcation in dynamical systems and the onset of chaos. Extension to fluid and magnetofluid systems with applications in geophysics and astrophysics. Students report on current papers and/or approved projects.
W. V. R. Malkus

18.358 Hydrodynamic Stability and Turbulence (A)

Prereq.: 18.354
G (2) **Next offfered 1987-88**
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 Stellar Dynamics and Galaxies (A)

Prereq.: 8.06, 18.076, or 18.302
G (2) **Next offered 1987-88**
3-0-9

Types and composition of galaxies, spiral arm and star formation. Dynamics of stellar systems and self-gravitating gaseous systems. Gravitational instability, density waves, dispersion relationship, resonances, self-excited spiral modes. Shock waves and star formation. Global modes, dynamical mechanisms for their excitation and maintenance. Simulation of real galaxies.
C-C. Lin

18.395 Group Theory with Applications to Physics (A)

Prereq.: 18.302 or 18.305 or 8.321
G (1) **Not to be offered 1987-88**
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
G (2)
3-0-9

A survey of quantum field theories with special emphasis on non-Abelian gauge field theories. Quantization. Path integration. Fields. Symmetry principles. Feynman rules. Renormalization.
H. Cheng

Theoretical Computer Science

18.400J Automata, Computability, and Complexity (Revised Unit)

(Same subject as 6.045J)
Prereq.: 18.063 or 18.310
U (1, 2)
4-0-8

See description under subject 6.045J.
A. R. Meyer

18.404J Theory of Computation (A except XVIII)

(Same subject as 6.840J)
Prereq.: 18.063 or 18.310
U (1)
3-0-9

A more extensive and theoretical treatment of the material in 6.045J/18.400J emphasizing computability, computational complexity, and mathematical logic. Reducibility, degrees of unsolvability, Kolmogorov complexity. Time and space measures on computation, efficient reducibility, complete problems. Decidable, undecidable, and inherently complex logical theories.
D. B. Shmoys

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

18.410J Introduction to Algorithms (Revised Units)

(Same subject as 6.046J)
Prereq.: 6.001, 18.063 or 18.310
U (1)
4-0-8

See description under subject 6.046J.
C. E. Leiserson, B. Awerbuch

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.
L. Heath

18.415J Advanced Algorithms (A)

(Same subject as 6.854J)
Prereq.: 6.851J/18.414J
G (1)
3-0-9

Continuation of 6.851J/18.414J, emphasizing fundamental algorithms and advanced methods of algorithmic design and analysis. Topics: Linear programming. Mastoid algorithms, maximum matching. Basis reduction, integer programming, polynomial factorization, diophantine approximation. Cryptography and randomness. Distributed algorithms, Byzantine Generals. Parallel algorithms and VLSI computation, universal simulations, area-time trade-offs. Computational geometry. Probabilistic analysis of algorithms. Advanced data structures.
R. L. Rivest

18.419 Topics in Algorithms and Complexity Theory (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

A seminar on advanced topics in algorithms and complexity. Current literature presented by students and instructors with a view toward preparing students for research in theory of algorithms and complexity. May be repeated for credit.
F. T. Leighton

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)
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.

18.423J Computability, Programming, and Logic (New)

(Same subject as 6.044J)
Prereq.: 18.063 or 18.310
U (2)
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 (1) **Not to be offered 1987-88**
3-0-9

See description under subject 6.830J.
A. R. Meyer

18.429J Algebraic Manipulation (A)

(Same subject as 6.856J)
Prereq.: 6.821, 18.063 or 18.310
G (2) **Next offered 1987-88**
3-0-9

See description under subject 6.856J.
R. E. Zippel

18.431J Graph Algorithms

(Same subject as 6.048J)
Prereq.: 18.063 or 18.310 or 18.314
U (1) **Not to be offered 1987-88**
3-0-9

Emphasizes the design of efficient algorithms for graph theoretic problems. Includes fast algorithms for: Shortest-paths problems, minimum spanning trees, depth-first search and graph decompositions, network flow algorithms, networks with upper and lower bounds, vertex and edge connectivity, maximum cardinality matchings, maximum weight matchings, planarity testing, distributed graph algorithms. Alternate years.
B. Awerbuch

18.433 Combinatorial Optimization and Linear Programming (New)

Prereq.: 18.06 or 18.710, 18.310
U (2)
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)
(Revised Content)

(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, C. E. Leiserson

18.436J Advanced Parallel and VLSI Computation (A)
(New)

(Same subject as 6.849J)
Prereq.: 18.435J/6.848J
G (2)
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.
F. T. Leighton, C. E. Leiserson

18.437J Distributed Algorithms (A)

(Same subject as 6.852J)
Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
3-0-9

See description under subject 6.852J.
N. Lynch

18.438 Distributed Graph Algorithms (A)
(New)

Prereq.: 18.410J/6.046J
G (2)
3-0-9

Design and analysis of efficient distributed algorithms in communication networks. Models of communication networks. Complexity measures for distributed algorithms. Network synchronization protocols. Tradeoffs among communication, time, and memory. Leader election. Graph problems in networks: minimum spanning tree. BFS, max-flow, DFS, shortest path, planar separator, etc. Unidirectional networks. Detection and resolution of deadlocks. Protocols in dynamic networks: routing, broadcast, resynch.
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.
Term 1: *C. F. Pearson*
Term 2: *R. M. Dudley*

18.441 Statistical Inference
(A except XVIII)

Prereq.: 6.041 or 18.440 or 18.313
U (2), G (2)
4-0-8

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.
N. Lange

18.443 Statistics for Applications
(A except XVIII)

Prereq.: 18.440 or 18.313 or 6.041
G (1)
4-0-8

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, analysis of variance and experimental design. Treatment more oriented toward application and less toward theory than 18.441.
R. E. Welsch

18.444 Probability and Statistics for Scientists and Engineers (A)

Prereq.: 18.02 or 18.021 or 18.022 or 18.023, 18.06
G (1)
Arr.

Accelerated introduction covering material in 18.440, 18.441 and part of 18.445J; for engineers and scientists talented mathematically and who need to apply statistical ideas but lack time for two or three semesters of course work. Case study point of view. Topics: probability, distribution expectation, central limit theorem, law of large numbers, estimation, hypothesis testing, confidence intervals, maximum likelihood, information, Neyman-Pearson theory, regression, design of experiments, decision theory, and Markov processes.
S. L. Zaleski

18.445J Introduction to Stochastic Processes (A)

(Same subject as 15.073J)
Prereq.: 18.313 or 18.440 or 6.041
G (1, 2)
4-0-8

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. Information: R. M. Dudley

18.446 Applied Time Series Analysis (A)

Prereq.: 18.441 or 18.443 or 15.075
G (1) **Next offered 1987-88**
4-0-8

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. Information: R. M. Dudley

18.448 The Analysis of Categorical Data (A)

Prereq.: 18.441 or 18.443 or 15.075
G (1)
4-0-8

Theory and application of log-linear models to multi-way contingency tables and other data sets where the dependent variable is categorical. Topics: the Poisson distribution, one-way, two-way, and multi-way 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.
N. Lange

18.453 Quality Control and Reliability (A)

Prereq.: 18.440; 18.441 or 18.443 or 15.075
G (1) **Next offered 1987-88**
3-2-7

Introduces statistical concept in quality control and reliability analysis. Topics: statistical design of Shewhart and CUSUM control charts; acceptance sampling, probabilistic representations and analyses of lifetime data; measurement and prediction of reliability characteristics. Interactive statistical graphics system used to demonstrate the methodology developed in the subject, as well as to provide a student laboratory environment. Information: R. E. Welsch

18.454 Sampling, Simulation, and Monte Carlo (A)

Prereq.: 18.440 or 18.313 or 6.041
G (1)
4-0-8

Introduction to principles and techniques of sampling for the purpose of a survey. Including: 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. Including: variance reduction, conditional Monte Carlo, control variates, antithetic variates, regression methods, Monte Carlo optimization, application to statistical inference problems. Information: R. M. Dudley

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 1987-88**
4-0-8

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, etc. Model II type of 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)
4-0-8

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. M. Dudley

18.457J Statistics for Model Building (A)

(Same subject as 15.076J)
Prereq.: 18.06; 18.443 or 15.075
G (2)
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 (1) **Next offered 1987-88**
3-0-9

Overview of robust statistical theory, including: asymptotic minimax, infinitesimal (bounded-influence) aspects, robust covariances and robust regression. Nonparametric methods which 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. Information: R. E. Welsch

18.465 Topics in Statistics (A)

Prereq.: Permission of Instructor
G (1)
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.: 18.125
G (1) **Next offered 1987-88**
3-0-9

Decision theory, estimation, confidence intervals, hypothesis testing. Introduces large sample theory. Asymptotic efficiency of alternative statistical procedures. Linear statistical inference. Permission of instructor required. Information: R. M. Dudley

Logic

18.504 Seminar in Logic

Prereq.: —
U (1)
3-0-9

Seminars for mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Students report on and discuss topics taken from current journals or from texts not regularly used in other mathematics subjects.
S. D. Friedman

18.511 Introduction to Mathematical Logic

Prereq.: —
U (2)
3-0-9

Propositional and predicate logic. Elementary model theory, completeness, compactness, and Lowenheim-Skolem theorems; elementary recursion theory, enumeration and recursion theorems. Gödel incompleteness theorems. Special additional topics as time permits. While this subject has no formal prerequisite, any Course XVIII subject with first decimal digit one or higher is adequate preparation. Information: S. D. Friedman

18.515 Mathematical Logic (A)

Prereq.: 18.511
G (1)
3-0-9

18.516 Mathematical Logic (A)

Prereq.: 18.515
G (2)
3-0-9

First-order logic. Completeness, compactness, Lowenheim-Skolem theorems. Type-omitting, categoricity. Incompleteness of arithmetic. Recursively enumerable sets and Turing degrees. Friedberg-Muchnik theorem. Zermelo-Fraenkel set theory. Ordinals and cardinals. Reflection principles, absoluteness. Consistency of axiom of choice and Generalized Continuum Hypothesis. Permission of instructor required for those not having 18.511.
M. S. Legrand

18.565 Recursion Theory (A)

Prereq.: 18.516
G (2)
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.
G. E. Sacks

18.585 Set Theory (A)

Prereq.. 18.516
G (1)
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.: 18.565, 18.585
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.
Term 1: *G. E. Sacks*
Term 2: *S. D. Friedman*

18.597 Universal Algebra (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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.
M. Haiman, G-C. Rota

Algebra and Number Theory

18.701 Algebra I

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
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.
18.701: *M. Artin*
18.702: *S. Kleiman*

18.703 Modern Algebra

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
U (2) SD
3-0-9

A one-term treatment, covering the traditional algebra topics which 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. D. Schafer

18.704 Seminar in Algebra and Number Theory

Prereq.: 18.702 or 18.703
U (2)
3-0-9

Seminars for mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Students report on and discuss topics taken from current journals or from texts not regularly used in other mathematics subjects.
M. Artin

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. Text: Atiyah and MacDonald.
D. J. Anick

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.
G. Lusztig

18.710 Abstract Linear Algebra

Prereq.: 18.002 or 18.02 or 18.021 or 18.022
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.
R. D. Schafer

18.711 Game Theory

Prereq.: —
U (1) **Next offered 1987-88**
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. Information: N. C. Ankeny

18.715 Topics in Homological Algebra (A)

Prereq.: 18.705
G (2) **Not to be offered 1987-88**
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. Topic for 1986-87: Homological algebra of commutative rings.
S. Kleiman

18.725 Algebraic Geometry (A)

Prereq.: 18.705
G (1) **Next offered 1987-88**
3-0-9

Introduces contemporary algebraic geometry. Centered around the basic techniques of the subject, including sheaf cohomology and the Riemann-Roch theorem for curves.
S. Kleiman

18.727 Topics in Algebraic Geometry (A)

Prereq.: 18.725
G (2) **Next offered 1987-88**
3-0-9

Topics vary from year to year; may be repeated for credit. Topics in the past few years have included the generalized Riemann-Roch theorem, etale cohomology, deformation theory, algebraic surfaces, the Picard scheme, and Hodge theory.
M. Artin

18.735 Topics in Algebra (A)

Prereq.: 18.702 or 18.703
G (2)
3-0-9

Topics vary from year to year; may be repeated for credit. Topics in the past few years have included noncommutative rings and algebras, non-associative algebras, local rings, algebraic K-theory, quadratic forms, and algebraic analysis.
B. Kostant

18.737 Linear Algebraic Groups (A)

Prereq.: 18.705
G (1) **Next offered 1987-88**
3-0-9

Introduces the classification of affine groups over an algebraically closed field via their representations as groups of invertible matrices.
M. Artin

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

Kač-Moody Lie algebras. Highest weight representations. Character formulas. Applications to combinatorics and invariant theory. Connection with the theory of theta functions and modular forms. 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 broad general introduction to Lie groups, suitable for physicists as well as mathematicians. Study of basic elementary examples: the classical matrix groups, the Galilei, Lorentz, and Poincare groups. Introduction to manifolds, general Lie groups, homogeneous spaces, and Lie algebras. Automorphism and adjoint groups.
R. Zierau

18.756 Analysis on Lie Groups (A)

Prereq.: 18.755
G (2) **Not to be offered 1987-88**
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 1987-88**
3-0-9

Lie groups, Lie algebras, and their representations. Induced representations. Representations of compact groups, nilpotent groups, and semi-simple groups. Analysis on semisimple Lie groups and symmetric spaces. Invariant differential operators and their role in representation theory.
B. Kostant

18.758 Representations of Lie Groups (A)

Prereq.: 18.757
G (2) **Not to be offered 1987-88**
3-0-9

Representations of semisimple Lie groups: theory of Harish-Chandra modules, Langlands' classification, Kazhdan-Lusztig conjectures. Decomposition of principal series representations, unitarity problem.
D. A. Vogan

18.769 Topics in Lie Theory (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
3-0-9

Topics vary from year to year; may be repeated for credit. Topic for 1986-87: Theory of Hecke algebras, with applications to representations of finite and p-adic semisimple groups; the Deligne-Langlands conjecture.
G. Lusztig

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

Reviews basic algebraic number theory. Classical formulation of class field theory, including existence and uniqueness of class fields, the conductor-discriminant formula, Artin's reciprocity law. Artin L-series. Adelic formulation. The simple algebra" approach. Applications to the study of arithmetic of cubic fields and (if time permits) to the theory of complex multiplication.
18.775: *B Kostant*
18.776: *N. C. Ankeny*

18.781 Theory of Numbers (New)

Prereq.: 18.701 or 18.703
U (1) **Not to be offered 1987-88**
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.
D. S. Freed

18.785 Analytic Number Theory (A)

Prereq.: 18.115
G (1) **Next offered 1987-88**
3-0-9

Analytic algebraic number theory. Functional equations of zeta and L-functions. Zero-free regions and prime number theorems. Applications to density theorems in algebraic number theory including Artin's conjecture on primitive roots.
H. M. Stark

18.786 Topics in Number Theory (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
3-0-9

Topics vary from year to year; may be repeated for credit. Topics in the past few years include: Diophantine analysis and transcendence; quadratic number fields and complex multiplication; automophoric forms: Topic for 1986-87: Theta functions and complex multiplication.
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)
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: *S. R. Costenoble*
Term 2: *Staff*
18.902: *J. R. Munkres*

18.904 Seminar in Topology

Prereq.: 18.901
U (2) **Next offered 1987-88**
3-0-9

Seminars for mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Students report on and discuss topics taken from current journals or from texts not regularly used in other mathematics subjects. Certain topics may require an additional prerequisite. Normally covers the same material as 18.902, but in seminar form.
D. M. Kan

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) **Next offered 1987-88**
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.
J. R. Munkres

18.950 Elementary Differential Geometry

Prereq.: 18.100, 18.901
U (1) **Not to be offered 1987-88**
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.
B. Ørsted

18.961 Elementary Differential Topology

Prereq.: 18.101, 18.901
U (2)
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' theorem, DeRham cohomology. Information: W. T. Shaw

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 geometry and classical dynamical systems.
V. W. Guillemin

18.969 Topics in Geometry (A)

Prereq.: 18.965
G (1)
3-0-9

Content varies from year to year; may be repeated for credit. Topic for 1986-87: Riemannian geometry and the Atiyah-Singer index theorem. Dirac operators, index density for families of operators, applications to group representations and L^2-index theorem. Permission of instructor required for students not having 18.965.
M. F. Vergne

18.975 Elliptic Operators (A)

Prereq.: 18.965
G (1) **Next offered 1987-88**
3-0-9

18.976 Elliptic Operators (A)

Prereq.: 18.975
G (2) **Next offered 1987-88**
3-0-9

Elliptic pseudodifferential operators and Fourier integral operators associated with them. Spectral theorems relating asymptotic properties of the spectrum to geometric properties of the bicharacteristics. The Selberg trace formula and various generalizations of it. 18.976 continues 18.975. Spectral properties of differential and pseudodifferential operators on open manifolds, scattering theory, non-self-adjoint operators.
V. W. Guillemin

18.994 Seminar in Geometry

Prereq.: —
U (2)
3-0-9

Seminars in several topics, for math majors. Each under direction of a faculty member whose interest is in the field of the seminar. Students report on and discuss topics from current journals or texts not regularly used in other math subjects. May be repeated for credit.
F. Morgan

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

20 Applied Biological Sciences

Undergraduate Subjects

Undergraduate Laboratory Subject

20.002 Laboratory in Applied Biology (Revised Unit)

Prereq.: —
U (1) LAB
2-8-5

Techniques in basic analytical biochemistry and separation science. Enzyme assays, disc gel electrophoresis, affinity chromatography, use of radioisotopes, experimental surgery, and other techniques. Recommended for students anticipating careers in applied areas of biology such as biochemical engineering, toxicology, pharmacology, nutrition, cancer research, genetic engineering, medicine.
R. S. Langer, A. M. Klibanov, J. M. Essigmann, M. R. Rosner, W. G. Thilly

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)
Arr.

Opportunities available in a wide variety of research programs in mammalian biochemistry and metabolism, clinical and public health nutrition, international nutrition, neuroendocrine regulation and endocrinology, toxicology, food science and technology, and biochemical engineering. Problems emphasize direct and active involvement of undergraduates in laboratory research which 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, clinical and public health nutrition, international nutrition, neuroendocrine regulation and endocrinology, toxicology, food science and technology, and biochemical engineering.
M. Chow

General Undergraduate Subjects

20.006 Chemicals and Human Disease (New)

Prereq.: —
U (1)
3-0-9

Introduction to the cascade of processes resulting in biological damage from exposure to environmental chemicals; focus on cancer and genetic disease. Design of predictive assays and application to pure compounds and complex mixtures. Emphasis on new technology for measurement of chemicals and patterns of genetic change in humans as a means of direct risk assessment.
W. G. Thilly

20.022J Human Physiology

(Same subject as 7.54J)
Prereq.: 7.05
U (1)
4-0-8

See description under subject 7.54J.
M. Krieger, R. D. Rosenberg

20.024 Pharmacology and Toxicology

Prereq.: 5.42, 7.05
U (2)
2-0-7

Basic biochemical approach to concepts in modern pharmacology and toxicology with emphasis on events occurring at the molecular level. Representative topics: molecular mechanisms of selectivity and drug action, rational drug design, drug delivery systems, molecular mechanisms of toxicity, and chemical carcinogenesis.
R. A. North, M. R. Rosner

20.025J Genetics (New)

(Same subject as 7.03J)
Prereq.:—
U (1)
4-0-8

See description under subject 7.03J.
H. R. Horvitz, R. A. Fitts.

20.026 Mechanisms of Pathogenesis (New)

Prereq.: 7.05, 7.03
U (1)
3-0-9

Basic review of disease-causing organisms, including bacteria, fungi, viruses, and protozoan parasites. Emphasizes modes of transmission, mechanisms of infection, and host responses. Special focus on the molecular biological properties of these pathogens that enable them to cause disease. In-depth study of several diseases such as AIDS, hepatitis, syphilis, plague, malaria. Strategies for diagnosis, treatment, and prevention of infectious diseases.
R. A. Fitts, M. Chow

General Graduate Subjects

20.100 Organ and Systems Pharmacology (New)

Prereq.: 20.022J or the equivalent
G (2)
3-0-9

An introduction to pharmacology. Normal organ and organ systems function and changes with disease. Therapeutic and toxic effects of drugs in normal function and in disease. Routes of administration, drug kinetics, and drug interactions. Designed to precede molecular pharmacology and toxicology as well as for those in other disciplines who desire a single pharmacology course.
R. S. Lee

20.111 Analytical Practices in Biochemistry (A)

Prereq.: 5.42, 7.05
G (2)
3-8-5

Advanced laboratory course dealing with protein isolation and characterization, molecular cloning, preparation of monoclonal antibodies, and cell culture technology.
J. M. Essigmann, R. S. Langer, M. R. Rosner, W. G. Thilly, A. M. Kilbanov

20.112 Control of Cellular Metabolism (A) (Revised Unit)

Prereq.: 7.05
G (2)
4-0-8

Designed to explore in depth the regulation of cell function by hormones. After an introduction on the control of cellular metabolism, the focus is on the action of representative hormones from each of three major classes: peptide, catecholamine, and steroid hormones. An integrated picture of the role of hormones and substrates in providing an interorgan metabolic control is then developed.
M. R. Rosner, H. N. Munro

20.113 Principles of Applied Biology (A) (New)

Prereq.: 20.111, 20.112
G (2)
3-0-6

Use of case studies to illustrate the integrated application of basic science and engineering tools to the solution of problems in the applied biological sciences. Topics include production and administration of therapeutic proteins, vaccine production, and development of diagnostic tests.
J. M. Essigmann, R. S. Langer

Graduate Subjects by Area

Nutritional Biochemistry and Metabolism

20.212 Nutrients: Their Metabolism and Role in Human Nutrition

Prereq.: 20.022, 7.05
G (1)
4-0-8

Function and metabolism of essential nutrients and factors that affect nutrient metabolism in the mammalian organism. Integrates knowledge of their biochemistry and physiology, based on studies in experimental animals, with a detailed discussion of human nutrition and metabolism including public health considerations. Emphasizes modern developments in nutritional research.
V. R. Young

20.214 Advanced Nutritional Biochemistry: Micronutrients (A)

Prereq.: 20.212
G (1)
4-0-8

Discusses and evaluates advances in research concerning the function and metabolism of essential nutrients. Emphasizes vitamins, trace elements, essential amino acids, fatty acids, lipids; e.g., connective tissue, collagen and vitamin C; calcium, homeostasis, bone metabolism and vitamin D; glycoproteins, membrane structure and vitamin A; lysine and carnitine; iron, zinc, copper, manganese, chromium, selenium and newer trace elements.
G. Wolf, Staff

20.311 Advanced Human and Clinical Nutrition (A)

Prereq.: 20.212
G (2)
4-0-8

Application of nutrition knowledge in the therapy and support of humans and in various physiological and pathological states. Nutritional requirements and status of humans. Nutrition of normal and low birth-weight infants; nutrition and immunity; the cancer and traumatized patient; patients with specific organ disease (liver, brain, kidney, endocrine system, gastrointestinal tract) and with genetic and other metabolic diseases, obesity, degenerative diseases, and the elderly.
V. R. Young, N. S. Scrimshaw, Staff

20.312 Clinical Nutrition in Practice (A)

Prereq.: 20.311
G (1, 2)
0-8-4

Coordinated practical experience on the application of nutrition in the management and care of hospitalized patients. Conducted in collaboration with units at hospitals within the Boston area.
N. S. Scrimshaw, Staff

Neuroendocrine Regulation and Endocrinology

20.511J The Human Nervous System: The Neurosciences I (A)

(Same subject as 9.014J, HST 130J)
Prereq.: Permission of Instructor
G (1)
6-3-6

See description under subject HST 130J.
A. M. Graybiel, M. P. Alexander, E. Bizzi, V. Chan-Palay, M. A. Moskowitz, R. A. North, S. Palay, T. Sabin, P. H. Schiller, H. R. Tyler, R. S. Williams, R. J. Wurtman

20.512J The Neurosciences II (A)

(Same subject as 9.015J)
Prereq.: Permission of Instructor
G (2)
6-0-9

Second semester subject of a two-semester sequence exposing graduate students to the broad range of contemporary topics in the neurosciences. Topics: 1)neurotransmission; 2)neurochemistry and neuropharmacology; 3)neuropsychology (somatosensory perception; memory; language; spatial capacities); 4)neuroendocrinology; and 5)development and plasticity of the nervous system.
R. J. Wurtman, M. R. Rosner, S. H. Corkin, R. D. McKay, W. G. Quinn, G. E. Schneider

20.517 Advanced Topics in Neurotransmitter Biochemistry (A)

Prereq.: 20.512J
G (1) **Next offered 1987-88**
2-0-4

Seminar on recent advances in neurotransmitter biochemistry; presentations by staff, guest lecturers, and students.
R. J. Wurtman

20.522 Cellular Neurophysiology (A)

Prereq.: 20.512J
G (1) **Not to be offered 1987-88**
3-0-9

Cellular-level electrophysiology. 1)Properties of excitable cells; linear and nonlinear equations describing behavior of membranes; 2)voltage and chemically gated channels; 3)neurophysiological aspects of synaptic transmission; 4)mathematical models of nerve cells in mammalian central nervous system and invertebrates. Alternate years.
R. A. North

Toxicology

20.611 General Toxicology (A)

Prereq.: 7.05
G (2)
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

20.612 Biochemistry of Xenobiotics (A)

Prereq.: 5.12, 7.05
G (1)
3-0-9

Major enzyme systems involved in metabolism of xenobiotic compounds with concentration on the mechanisms of activation and detoxification and interaction of metabolites with cellular macromolecules. A detailed examination into the mechanisms of oxidation, reduction, hydrolysis and conjugation reactions especially where these reactions may result in the potential generation and removal of toxic intermediates. Emphasizes events occurring at the molecular level.
M. A. Marletta

20.613 Genetic Toxicology (A)

Prereq.: 7.28
G (1) **Next offered 1987-88**
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 1987-88**
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 skill 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 1987-88**
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 effect of these properties 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 1987-88**
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

20.732 Physical Chemistry of Biomaterials (A)

Prereq.: 5.60
G (2) **Not to be offered 1987-88**
3-0-6

Physicochemical principles governing the behavior of industrial biomaterials, including foods. Applications to representative industrial problems. Colloidal and surface phenomena. Conformational transition in biopolymers. Diffusion in polymers and in complex systems. Phase transformations in biomaterials. Kinetics of chemical reactions of significance in processing and storing foods and other biomaterials. Simulation of reactions occurring in processing and storage. Alternate years.
M. Karel, A. M. Klibanov

20.734 Applied Enzymology (A)

Prereq.: 7.05
G (1) **Not to be offered 1987-88**
3-0-6

Production and purification of commercial enzymes. Mechanisms of practically important enzymes. Protein stability and denaturation. Enzyme inactivation and approaches to stabilization of enzymes. Immobilized enzymes, coenzymes, and whole cells. Immobilized biocatalyst reactors. Enzymatic processes in heterogeneous systems. Fundamentals of practical applications of enzymes in food and chemical industries, in analyses and medicine; future trends. Economic, health, and legal aspects of the use of enzymes. Alternate years.
A. M. Klibanov

20.743 Applied Microbiology (A)

Prereq.: 20.721
G (2) **Not to be offered 1987-88**
3-0-6

Discussions center on sporulating and toxin-producing microorganisms. Focuses on the physiology, biochemistry and genetics of sporulation and toxicology. Topics in sporulation include: sporulation, dormancy and resistance, activation, germination and outgrowth. Topics in toxicology include: genetics, mechanisms of action, and assay systems.
A. J. Sinskey

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 micro-organisms. 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) (New)

(Same subject as 10.57J)
Prereq.: Permission of Instructor
G (2)
3-0-6

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, to whole-cell metabolism, to pure and mixed population dynamics and stability, to full bioreactor models are considered. Emphasis 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.
Greg Stephanopoulos, A. J. Sinskey

20.803J Biotechnology of Mammalian Cells (New)

(Same subject as 10.56J, 7.52J)
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.
H. F. Lodish, A. J. Sinskey, D. I. C. Wang

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.: 20.811
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. Class work in various fields not covered by regular subjects of instruction.
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

21 Humanities

Literature

21.UR Research in Humanities

Prereq.: —
U (1, 2)
Arr.

Individual participation in an ongoing research project. For students in the Undergraduate Research Opportunities Program. Consult T. R. Merritt.

21.TH T Humanities Pre-Thesis Tutorial (Revised Unit)

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.
T. R. Merritt

21.TH Undergraduate Thesis in Humanities (Revised Unit)

Prereq.: 21.THT
U (1, 2)
Arr.

Completion of work on the senior major thesis under supervision of a faculty tutor. Includes oral presentation of the state of the thesis in 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).
T. R. Merritt

21.E T Pre-General Examination Tutorial (Revised Unit)

Prereq.: As specified for particular field
U (1, 2)
1-0-5

First-stage preparation for 21.EX Humanities General Examination. Taken during the first term of the student's two-term commitment to reviewing and organizing knowledge of the major field. Student works closely with an individual faculty tutor. Required for certain students in some fields under Courses XXI, XXI-E, and XXI-S for whom the General Examination is a degree requirement.
T. R. Merritt

21.EX Humanities General Examination (Revised Unit)

Prereq.: 21.E T
U (1, 2)
Arr.

Study to complete preparation for the General Examination in the major field, culminating in the Examination itself. Student continues to work closely with the faculty tutor, regularly discussing the materials under review. Required of certain students in Courses XXI, XXI-E, and XXI-S (see degree requirements for specific fields).
T. R. Merritt

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 Humanities Distribution credit. 2) Intermediate subjects (21.021-21.120), some carrying Humanities 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 Foundations of Western Literature: Homer to Dante (Revised Unit)

Prereq.: —
U (1, 2) HUM-D
3-0-9

Careful reading and critical examination of literary texts, knowledge of which is essential to understanding the European tradition in imaginative literature. Stresses appreciation and analysis of works which came to represent the common cultural possession of the modern age. Readings include Homer, Sophocles, Euripides, Aristotle (the *Poetics*), Horace, Virgil, Ovid, Augustine, and Dante.
Term 1: *D. M. Halperin*
Term 2: *S. Mullaney*

21.002 Classics of European Literature

Prereq.: —
U (1, 2) HUM-D
3-0-6

Masterworks of epic, drama, lyric, novel, and film. Includes works by such writers as Cervantes, Shakespeare, Donne, Milton, Molière,

Goethe, Tolstoy, Chekhov, Yeats, Mann, and at least one film. Emphasizes intrinsic merit of each text and the social or mythological function of literature, its role as a carrier (and critic) of the central moral, political, and psychological beliefs of its society.
Term 1: *C. G. Wolff*
Term 2: *D. M. Halperin*

21.003 Introduction to Fiction

Prereq.: —
U (1, 2) HUM-D
3-0-6

Introduces prose narrative, especially the novel. Emphasizes literary structure, social and historical context, the relations between fiction and its audience. Reading lists vary among the sections but include works by such writers as Fielding, Laclos, Austen, Dickens, Stendhal, E. Brontë, Tolstoy, Conrad, Joyce, Faulkner, Lawrence, Kafka, Lu Hsun, D. Lessing, T. Olsen, G. Garcia-Marquez, C. Achebe.
Term 1: *R. Goldberg, L. Kampf*
Term 2: *I. Tayler, C. G. Wolff*

21.004 Introduction to Poetry

Prereq.: —
U (1, 2) HUM-D
3-0-6

Emphasis on learning how to enjoy poetry and on the evolution of poetic form. Syllabus varies somewhat from year to year but always includes authors from this list: Chaucer, Spenser, Shakespeare, Milton, Donne, Pope, Wordsworth, Keats, Browning, Yeats, Auden, Eliot, Whitman, Williams, Frost, Stevens.
Term 1: *T. R. Merritt*
Term 2: *J. Hildebidle*

21.005 Introduction to Drama

Prereq.: —
U (1, 2) HUM-D
3-0-6

Extensive reading of dramatic masterworks. Emphasizes development from ancient to contemporary theatre of drama's constituent elements (action, character) and the problematic relation of text to performance. Typically includes Sophocles, Shakespeare, Racine, O'Neill, Beckett.
Term 1: *P. S. Donaldson*
Term 2: *T. C. Theoharis*

21.006 Introduction to American Literature

Prereq.: —
U (1, 2) HUM-D
3-0-6

Surveys major American texts, stressing literary and ideological traditions and the emergence of a national literature. Principal readings in Emerson, Whitman, Hawthorne, Melville, Twain, Dickinson James, Wharton, Faulkner, Fitzgerald, Ellison, Stevens, Frost.
Term 1: *W. Kelley, A. Lang, C. G. Wolff*
Term 2: *A. Lang, L. Marx*

21.009 Shakespeare

Prereq.: —
U (1, 2) 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, S. Mullaney*
Term 2: *P. S. Donaldson, S. Mullaney*

21.010 Literature and Film

Prereq.: —
U (1, 2) HUM-D
4-0-5

Close reading and viewing of masterpieces of literature and film, with attention to narrative values. Emphasizes ways in which these are modified by the nature of media. Authors and directors vary with topic, but include figures such as Homer, Shakespeare, Austen, Dickens, Conrad, Chaplin, Ford, Coppola, others. Term 1: Information A. C. Kibel. Term 2: Shakespeare on film.
Term 1: *Staff*
Term 2: *P. S. Donaldson*

Intermediate Subjects

Genres and Themes

21.021 Comedy

Prereq.: —
U (1, 2) HUM-D
3-0-6

Studies various works designed to make us laugh; investigates the culture that produced them, and various theories of comedy. Authors and directors include: Aristophanes, Plautus or Terence, Chaucer, Shakespeare, Molière, Austen, Joseph Heller, Chaplin, Keaton, others.
R. B. Goldberg

21.022 Tragedy

Prereq.: —
U (1) 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: Science Fiction

Prereq.: One subject in literature
U (2)
4-0-5

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.
H. Thomas

21.031 The Film Experience

Prereq.: —
U (1, 2) HUM-D
3-0-6

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*
Term 2: *W. J. Paul*

21.032J American Television: A Cultural History

(Same subject as STS 625J)
Prereq.: One subject in literature
U (2)
3-0-6

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)
3-2-4

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 1986-87: Hitchcock, Chabrol, Lang.
W. J. Paul

21.041J Women in Literature (Revised Content)

(Same subject as SP 436J)
Prereq.: One subject in Literature
U (2)
3-0-6

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 Stowe, Dickens, Eliot, Wharton, James, Gissing, Lessing.
A. Lang

21.042 Friendship, Love, and Desire

Prereq.: One subject in literature
U (2)
3-0-6

Changing significance of friendship and love in Western culture. Self and other in literary and historical perspective. Studies different values associated with emotions in personal, political, philosophical, religious, and psychological contexts in different ages. Readings in Plato, Aristotle, Augustine, Dante, Shakespeare, Goethe, Flaubert, Proust, Mann, Nabokov, Updike, and others. Syllabus varies.
D. M. Halperin

21.043 The Novel East and West

Prereq.: One subject in literature
U (1)
3-0-6

The novel of the Far East and the Third World in the 20th century. Readings divided equally between European and indigenous perspectives. Emphasis on such topics as the modern Japanese novel, the literature of European colonialism, heroism in East and West, images of the West. Novelists featured include such figures as Forster, Narayan, Tanizaki, Mishima, Endo, Lu Hsun, Pai Hsien-Yung, Eileen Chang, Conrad, and Naipaul.
S. Cheng

Periods of World Literature

21.060 Medieval Literature

Prereq.: One subject in literature
U (2)
3-0-6

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. Information: A. C. Kibel.

21.063 Renaissance Literature

Prereq.: One subject in literature
U (2) **Next offered 1987-88**
3-0-6

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

21.065 Milton

Prereq.: One subject in literature
U (1)
3-0-6

Studies in *Paradise Lost* and Milton's other works, both verse and prose, in the context of his life, literary tradition, and the social, cultural, and religious upheavals that produced the English Revolution in 1640. Discussion alternating with lecture, several short papers.
S. Mullaney

21.070 Eighteenth-Century Literature

Prereq.: —
U (1)
3-0-6

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: Addison and Steele, Defoe, Swift, Astell, Pope, Montagu, Richardson, Fielding, Johnson.
R. Perry

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.
R. Goldberg

21.075 Irish Literature

Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

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.
J. Hildebidle

21.076 Romantic Poetry

Prereq.: One subject in literature
U (2) **Next offered 1987-88**
3-0-6

Close readings of the major British Romantic poets (Blake, Wordsworth, Coleridge, Byron, Scott, Burns, Shelley, Keats), with some attention to their adaptation of older literary forms, especially Medieval narrative and Renaissance verse. Discussion and several short papers.
T. C. Theoharis

21.078 The Realistic Novel

Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

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: Russian and the Modern Age

Prereq.: —
U (2)
3-0-9

Studies of artistic vision in modernizing Russia. Analyses of *Notes from 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)
3-0-6

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 (1)
3-0-6

Reading and discussion of major modern plays (and some films) from Ibsen through Beckett and beyond. Features works by such authors as: Shaw, Chekhov, Lorca, Pirandello, Ionesco, Brecht, Miller, O'Neill, Williams, Sartre, Hansbury, and Weiss.
W. J. Paul

21.087 Modernist Poetry

Prereq.: One subject in literature
U (2)
3-0-6

Studies important trends in modern thought and sensibility as reflected in the poetry of the 20th century. Readings center on Yeats, Eliot, Pound, Williams, H. D., and Frost, with some consideration of such later figures as Roethke, Plath, Berryman, Wilbur, Rich, and Hughes.
T. C. Theoharis

21.088 Contemporary Literature

Prereq.: One subject in literature
U (2)
3-0-6

Fiction, drama, poetry, and film, mostly of the 1960s and 70s. 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: lectures, discussion, several short papers.
D. Thorburn

American Literature

See also 21.006 Introduction to American Literature

21.101 The American Novel

Prereq.: —
U (1, 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.
Term 1: *A. Lang*
Term 2: *C. G. Wolff*

21.103J Literature, Ideology, and National Experience in the US

(Same subject as STS 601J)
Prereq.: —
U (2) HUM-D
3-0-6

See description under subject STS 601J.
L. Marx

21.104 Race and Identity in American Literature (New)

Prereq.: —
U (2)
3-0-6

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, others. Discussion, occasional brief lecture.
J. Hildebidle

21.105 American Voices

Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

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, Linda Brent, Michael Gold, Studs Terkel, Maxine Hong Kingston. Restricted to 25 students.
L. Kampf

21.112 American Authors

Prereq.: One subject in literature
U (1) **Next Offered 1987-88**
3-0-6

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.
C. G. Wolff

21.120 American Themes

Prereq.: One subject in literature
U (2) **Next Offered 1987-88**
3-0-6

Examines unifying themes in American culture through a close reading of literary and extraliterary 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. Information: A. C. Kibel.

Seminars

21.171 Literary Interpretation

Prereq.: Two subjects in literature
U (1)
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. Topic 1986-87: Theory and Practice of the Novel.
A. C. Kibel

21.172 Studies in Fiction

Prereq.: Two subjects in literature
U (1)
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. Topic for 1986-87: British Fiction Between the Wars.
D. M. Halperin

21.173 Studies in Drama

Prereq.: Two subjects in literature
U (1, 2)
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 1986-87: Term 1: O'Neill, Pinter, and Beckett. Term 2: Plays and Playwriting. Writing of dialogue, scenes, and possibly a one-act play. Reading of recognized playwrights as appropriate. Visits to local dramatic productions on occasion.
Term 1: *T. C. Theoharis*
Term 2: *A. R. Gurney, Jr.*

21.174 Studies in Poetry

Prereq.: Two subjects in literature
U (2)
3-0-9

Extensive reading in a few major poets. Emphasizes the evolution of each poet's work, and questions of poetic influence and literary tradition. Topic for 1986-87: Blake and the Romantics.
I. Tayler

21.175 Major Authors

Prereq.: Two subjects in literature
U (1, 2) **Next offered 1987-88**
3-0-9

Close study of a limited group of writers.
Term 1: *T. R. Merritt*
Term 2: *W. B. Watson*

21.176 Studies in Film and Media (New)

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 1986-87: Hollywood Comedy of the Depression.
W. J. Paul

21.177J Problems in Cultural Interpretation

(Same subject as SP 402J)
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 1986-87: Feminist Literary Criticism.
R. Perry

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 and the Department of Humanities. 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

See 21.708 The Bible and 21.709 The Greeks

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 Humanities Distribution credit. A variety of literature subjects given in the original language as well as some given in English also offer Humanities 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 21.325-21.340.

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 the four basic language skills and to French culture. Emphasizes intensive oral training; practice in writing and reading; regular use of language lab.
J. Wool

21.202 French II

Prereq.: French I
U (1, 2)
4-0-8

Practice in conversation, vocabulary building. Completion of basic grammar. Supplementary readings. Continued use of language laboratory.
J. Wool

21.203 French III

Prereq.: French II
U (1, 2) HUM-D
4-0-8

Practice in spoken French to develop oral skills. Grammar review; further development of writing skills; reading and discussion of literary and cultural materials. Continued use of language laboratory, aural and video.
I. de Courtivron

21.204 French IV

Prereq.: French III
U (1, 2) HUM-D
4-0-8

Final subject in French language sequence. Prepares students for intermediate subjects in French literature and civilization. Reading and discussion of the contemporary novel, theatre, poetry. Perfecting of writing skills through frequent essays. Continued use of language laboratory, aural and video.
G. Furstenberg

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) **Next offered 1987-88**
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.
J. Brami

21.209 French Civilization

Prereq.: French IV
U (1) HUM-D **Next offered 1987-88**
3-0-6

Investigates major social, ideological, and aesthetic currents and cultural myths in French civilization from its beginnings to the eve of the Revolution. Study of selected texts of the Middle Ages, the Renaissance, the 17th Century, and the Enlightenment. Class presentations covering developments in painting, architecture, and music. Devotes special attention to the improvement of French language skills.
E. B. Turk

21.211 Introduction to French Literature

Prereq.: French IV
U (1) HUM-D
3-0-6

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.
J. Brami

21.212 The French Press

Prereq.: French IV
U (2)
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.
C. Lecuyer

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 (1) **Not to be offered 1987-88**
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

21.214 From Enlightenment to Revolution: France in the 18th Century

Prereq.: French IV
U (1) **Next offered 1987-88**
3-0-6

Studies the major historical, philosophical, literary, and cultural developments that structure the French Enlightenment and lead to the French Revolution. Readings and discussions focus on the fundamental issues representative of 18th-century philosophy and culture: man and his relationship to the world, to his scientific and philosophical knowledge, to God, to woman, and to his fellow man and society. Texts include selections from Beaumarchais, Diderot, Marivaux, Montesquieu, Rousseau, Voltaire.
K. Crecelius

21.217 Introduction to French Poetry

Prereq.: French IV
U (1) HUM-D **Not to be offered 1987-88**
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 (2) HUM-D **Not to be offered 1987-88**
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 19th-Century Novel (New)

Prereq.: French IV
U (1) **Next offered 1987-88**
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.
K. Crecelius

21.222 The French Novel in the 20th Century (Revised Unit)

Prereq.: French IV
U (2) **Next offered 1987-88**
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 (New)

Prereq.: French IV
U (1) **Next offered 1987-88**
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.
R. E. Jones

21.224 Artistic and Intellectual Currents of Modern France: Literature and Ideology (New)

Prereq.: French IV
U (2) HUM-D **Not to be offered 1987-88**
3-0-6

Traces the changing philosophical, political, and artistic currents of 20th-century France as reflected in significant fiction, essays, and films produced between World War I and the present. Writers and artists include Breton, Dali, Malraux, Sartre, Beauvoir, Camus, Sarraute, Robbe-Grillet, Resnais, Ophuls, Bernard-Henri Levy, Witting, Cixous. Emphasizes the role of art in creating and promoting new values and the movements of Surrealism, Existentialism, the New Novel, New Philosophy, and Feminism.
I. De Courtivron

21.225 Representations of Love in French Literature

Prereq.: French IV
U (2) HUM-D **Not to be offered 1987-88**
3-0-6

Examines a wide variety of texts which deal explicitly with the theme and the problems of love. Focuses on four main periods and types of representations of love: the medieval period and its code of chivalry, the 17th century and its debate between passion and reason, the pre-romantic and romantic period and the elaboration of a rhetoric of seduction, and the final perversion of the romantic ideal. Authors read include Marie de France, Molière, Racine, Prévost, Laclos, Constant, Musset, Balzac, Flaubert, Duras.
K. Crecelius

21.226 Introduction to French-Canadian Literature

Prereq.: French IV
U (2) **Next offered 1987-88**
3-0-6

Study of French-Canadian literature and culture of the 20th century. Authors read include Gabrielle Roy, Marie-Claire Blais, Anne Hébert, Jacques Ferron, Michel Tremblay. Students situate authors' works in their social, political, and linguistic context; discuss the relationship of *littérature québecoise* to literary movements in France; and examine the preeminence of women writers in this national literature.
K. Crecelius

21.228 French Film Classics

Prereq.: French IV
U (1) **Next offered 1987-88**
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.

Subjects numbered 21.249 to 21.253 may count to fulfill a concentration or a major in German only upon special arrangement with one of the Foreign Language concentration and major advisors. Contact Foreign Languages and Literatures Office, x4771.

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.
R. Di Donato

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 communication skills.
R. Di Donato

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.
E. Waldstein

21.233 German III

Prereq.: German Review or German II
U (1, 2) HUM-D
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.
D. Dollenmayer

21.234 German IV

Prereq.: German III
U (1, 2) HUM-D
4-0-8

Systematic development of reading and writing skills through discussion of literary texts (Grimm, Kafka, Brecht) and training in composition. Sharpening of oral communication skills through weekly use of authentic tapes and a functional approach to vocabulary and grammar.
C. J. 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 1987-88**
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 (2) **Not to be offered 1987-88**
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, R. Di Donato

21.239 Introduction to German Literature

Prereq.: German IV
U (2) HUM-D **Next offered 1987-88**
3-0-6

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.
D. Dollenmayer

21.240 German Culture and Society: 1750-1914 (Revised Content)

(21.247)
German IV
U (1) HUM-D **Next offered 1987-88**
3-0-6

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.
E. Waldstein.

21.241 Fantasy and Reality in 19th-Century German Literature (Revised Content)

Prereq.: German IV
U (2) HUM-D **Next offered 1987-88**
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 non-traditional ones (letters, diaries, reportage, pamphlets). Writers include F. Schlegel, B. v. Arnim, Hölderlin, Kleist, Grillpartzer, Heine, Büchner, Keller, Fontane, Storm, Droste-Hülshoff, Hauptmann and Nietzsche.
M. Geisler, E. Waldstein

21.242 From the Great War to an Uncertain Peace: 20th-Century German Literature (New)

Prereq.: German IV
U (1) **Not to be offered 1987-88**
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.
J. Rosellini

21.243 German Short Fiction

(21.242)
Prereq.: German IV
U (1) HUM-D **Not to be offered 1987-88**
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.
D. Dollenmayer

21.244 Topics in German Literature (New)

Prereq.: German IV
U (2)
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. Topic for 1986-87: Friends in Need: Myths of Friendship and Community in German Literature. Readings include Das Nibelungenlied, Grimmelshausen, Schiller, B. v. Arnim, Kaiser, Döblin, Christa Wolf; films by Pabst, Syberberg, Wenders.
M. Geisler

21.249 Introduction to German Poetry

Prereq.: German IV
U (2) HUM-D **Next offered 1987-88**
3-0-6

Reading and studying poetry as an expression of feeling, thinking, and being. Highlights poetry of Goethe, Schiller, Novalis, and Eichendorff; then continues with major works of two of the most influential 20th-century poets: Rilke and Celan; concludes with the sampling of the work of a current poet. Includes a careful study of recordings of professional recitations of poems, and of Lieder. Readings and instruction in German. Discussion in German and English. The paper usually in English.
M. Dyck

21.250 Introduction to German Drama

Prereq.: German IV
U (1) HUM-D
3-0-6

Introduces the classical (Lessing, Goethe, Schiller, Kleist), contemporary (Büchner, Hauptmann, Kaiser, Brecht), and current German drama (Frisch, Dürrenmatt, Weiss, Handke, Hacks, and others). The general nature of drama and the special features of this genre in its German manifestations (particularly tragedy, comedy, and various modern and post-modern forms and techniques). Discusses recordings of German productions of about half the plays covered. Conducted primarily in German.
M. Dyck

21.251 Goethe: *Faust*

Prereq.: German IV
U (2)
3-0-6

A succinct introduction to Goethe's life, work, and thought, parallel to a close study of both parts of *Faust,* with attention to the tradition of the theme and the major versions by other authors (Marlowe, Valéry, Thomas Mann). Conducted primarily in German, with readings in the original and lectures in German.
M. Dyck

21.252 The Modern German Novel

Prereq.: German IV
U (1) **Next offered 1987-88**
3-0-6

Reading and discussion of six German novels from 1890 to present. Selected titles from Thomas Mann, Heinrich Mann, Hauptmann, Broch, Musil, Jünger, Kafka, Hesse, Langgässer, Grass, and one current example each from West and East Germany. Basic elements of fiction and of the novel. Students read three novels in entirety and selections from rest. Readings and instruction in German. Discussion in English and German. Paper normally in English.
M. Dyck

21.253 The World of Kafka

Prereq.: German IV
U (1) **Next offered 1987-88**
3-0-6

You are invited to enter the weird world of Kafka through his major and minor prose works: the novels *(Der Prozess, Das Schloss, Amerika)* and such shorter narrative pieces as *Das Urteil, Die Verwandlung, Ein Hüngerkunstler,* and others. Instruction and readings in German. Paper in English.
M. Dyck

Greek

21.255 Classical Greek I

Prereq.: —
U (1) **Next offered 1987-88**
4-0-8

Study of Attic Greek as a cultural subject. Basic text Chase and Phillips, *A New Introduction to Greek,* is supplemented with various readers and xeroxed passages. Through special emphasis and quotations the cultural significance of the linguistic matters treated are brought into focus. Greek views of fate, love, death compared and contrasted with Christian and modern ones. By the end of the first term students have read the creation-account from *Genesis* and the Christmas story from *Luke.*
H. A. T. O. Reiche

21.256 Classical Greek II

Prereq.: Greek I
U (2) HUM-D **Next offered 1987-88**
4-0-8

Emphasizes syntax and easy composition. In addition to Chase and Phillips students do easy selections from Lucian, Xenophon, and Plato. Attention given to the subject matter covered in the readings to bring out its significance and thus to help motivate continued student interest. Emphasizes recognition rather than memorization. Also, selections from Greek mathematics, medicine, and astronomy.
H. A. T. O. Reiche

21.257 Greek Literature I

Prereq.: Permission of Instructor
U (1) **Next offered 1987-88**
4-0-8

First exposure to complete, relatively easy, texts such as Plato's *Apology* or *Crito* or *Ion* or *Eutyphro* and, in poetry, Euripides' *Hippolytus* or Aristophanes' *Clouds.* Students encouraged, through outside readings of distinguished secondary work and class discussion, to place the works studied in a broader context of literary, philosophical, and cultural history. Introduces problem of style, in part through suitably chosen exercises in prose composition. Selections from *Odyssey.*
D. M. Halperin

21.258 Greek Literature II

Prereq.: Greek Literature I
U (1) **Next offered 1987-88**
4-0-8

Exposure to complete texts continued, but to texts of somewhat greater inherent difficulty, both prose and poetic. Some lyric poets; one or two complete books of either *Odyssey* or *Iliad;* Sophocles' *Antigone.* Selected outside reading and class discussion of distinguished secondary work (e.g., Matthew Arnold, Bowra, Jaeger, Kitto, Stanford) to supplement the linguistic side. Lysias' *Against Eratosthenes* in its historical context and as model for occasional exercises in prose composition.
H. A. T. O. Reiche

21.259 Greek Literature III

Prereq.: Greek Literature II
U (1) **Next offered 1987-88**
4-0-8

Selected books of *Iliad* coupled with introduction to problems of oral culture and the so-called Homeric Question. Then either Aeschylus' *Prometheus Bound* or Sophocles' *Oedipus King.* Finally, Pericles' *Funeral Oration* from the second book of Thucydides. Reading and discussion of such additional works as Cornford, *Thucydides Mythistoricus* and Nietzsche's *Birth of Tragedy* serve to raise the questions of historical "truth" and the meaning of tragedy.
H. A. T. O. Reiche

21.260 Greek Literature IV

Prereq.: Greek Literature III
U (2) **Next offered 1987-88**
4-0-8

Aeschylus' *Agamemnon,* Euripides' *Bacchae* (or Aristophanes' *Frogs),* and Thucydides' account of the Sicilian Expedition (Bks VI and VII) or Bks I and X of Plato's *Republic.* Attention to selected textual problems, metre, style, and idiom. Those interested may flesh out Plato's Myth of Er with selections from Plato's *Timaeus.*
H. A. T. O. Reiche

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 as a prerequisite for effective communication in Russian and as a basis for acquiring reading and writing skills. Extensive use of language laboratory.
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 a gradual transition to reading and writing. The second part of the term seeks to integrate language skills and develop control of vocabulary through readings which serve as a basis for conversation and composition. Regular work in language laboratory.
A. Perkins

21.263 Russian III

Prereq.: Russian II
U (1) HUM-D
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. Information: C. V. Chvany

21.264 Russian IV

Prereq.: Russian III
U (2) HUM-D
4-0-8

Reading of literary and expository texts selected to provide an understanding of Soviet life and culture. Emphasizes development of skill and confidence in reading unedited texts. Aural comprehension developed through brief lectures on cultural topics as well as through taped materials. Discussion and brief papers based on readings. Attention to problems of grammar and style, with a view to improving facility in oral and written expression.
E. Semeka.

Advanced Subjects

21.265 Advanced Russian Composition and Conversation

Prereq.: Russian IV
U (1) **Next offered 1987-88**
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. Emphasis varies in alternate years. Extensive use of taped materials. Conducted in Russian.
C. V. Chvany

21.266 Advanced Spoken Russian

Prereq.: Russian IV
U (1) **Not to be offered 1987-88**
3-1-5

Practice in speaking and understanding modern colloquial Russian. Extensive use of taped materials for intonation practice and aural comprehension. Reading of short drama, fiction, and nonfiction featuring dialogues. Increases control of an active vocabulary and its grammar, while expanding passive vocabulary and aural comprehension. Practice in recognizing regional, social, ethnic dialects. Comparison of literary and textbook dialogues with recordings of actual conversations.
C. V. Chvany

21.268 Topics in Russian and Soviet Culture for Bilinguals

Prereq.: Proficiency in Russian as determined by instructor
U (1) HUM-D **Next offered 1987-88**
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 deal with matters such as individual vs the state; generation gaps; men, women, and family. The focus this year is on Okudzhava, Galich, and Vysotsky.
E. Semeka

21.269 Introduction to Russian Literature I

Prereq.: Russian IV
U (2) **Next offered 1987-88**
3-0-9

The subject has a double aim: a) continued practice in composition and stylistics; b) acquaintance with the foundation of modern Russian literature through the most important and characteristic works of Pushkin, in verse and in prose, including *Evgenij Onegin*. Provides a context through short works by other Russian writers, selected mostly from Obolensky's anthology, *The Heritage of Russian Verse*. Introduces critical method and literary terminology, as the texts are analyzed both historically and structurally. Conducted in Russian.
C. V. Chvany

21.270 Pushkin and His Successors

Prereq.: Russian IV
U (2) HUM-D **Not to be offered 1987-88**
3-0-9

Acquaints the student with the foundations of modern Russian literature through the most important and characteristic works of Pushkin and his successors, mainly Turgenev and Chekhov. Among works analyzed are *Eugene Onegin* by Pushkin, *Asja* and mystical stories by Turgenev, *The Darling* and *In the Cart* by Chekhov. Intensive work on composition and stylistics. Conducted in Russian.
K. Pomorska

21.271 Contemporary Russian Prose and Poetry

Prereq.: Russian IV
U (1) **Not to be offered 1987-88**
3-0-9

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.
K. Pomorska

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.
D. Morgenstern

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.
J. W. Harris

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.
E. Lilienfeld

21.278 Spanish IV

Prereq.: Spanish III
U (1, 2) HUM-D
4-0-8

Continued improvement in oral and written comprehension and expression for literary, language, and cultural studies, as well as for non-scholarly use of Spanish. Materials include film and radio broadcasts in addition to a selection of poetry and prose by modern masters, such as Borges, García Márquez, Rulfo, and Lorca.
E. Lilienfeld

21.279 Oral Communication in Spanish

Prereq.: Spanish II
U (2) **Next offered 1987-88**
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
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) HUM-D **Not to be offered 1987-88**
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 non-literary readings are in English; class discussions in Spanish.
D. Morgenstern

21.283 Spanish Drama Workshop

Prereq.: Spanish IV
U (2)
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.
M. Delgado

21.284 Introduction to Latin American Culture

Prereq.: Spanish IV
U (2) HUM-D **Next offered 1987-88**
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, art, and music 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 **Not to be offered 1987-88**
3-0-6

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 (2) HUM-D **Not to be offered 1987-88**
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: these include texts by Colón, Bernal Díaz del Castillo, Sor Juana Inés de la Cruz, Esteban Echeverría, José Hernández, Ricardo Palma, and José Martí.
E. Garrels

21.287 Twentieth-Century Latin American Literature: The Alchemist's Laboratory

Prereq.: Spanish IV
U (2) HUM-D **Next offered 1987-88**
3-0-6

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 Dario, Vallejo, Quiroga, Neruda, Arguedas, Rulfo, Borges, and García Márquez.
E. Garrels

21.288 The Modern Short Story in Spain and Latin America

Prereq.: Spanish IV
U (2) **Next offered 1987-88**
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, Martín Gaite, Aub, and Peri Rossi.
M. Resnick

21.290 Literature and Social Conflict: Perspectives on Modern Spain

Prereq.: Spanish IV
U (2) HUM-D **Next offered 1987-88**
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

21.291 The Family in Spanish American Literature

Prereq.: Spanish IV
U (1) **Next offered 1987-88**
3-0-6

Considers works of modern Spanish American literature which deal with relations of power and the definition of sex roles in the Hispanic family. Also considers the use of the family as a metaphor for larger societal units, the idealization of the family, and its portrayal as a haven from society's indifference and chaos. Works include novels and short stories by Donoso, Cortázar, García Márquez, Villaverde, Bombal, de la Parra, as well as Sarmiento's autobiography. Conducted in Spanish.
E. Garrels

21.292 Cervantes and His Age

Prereq: Spanish IV
U (1) **Next offered 1987-88**
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' 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 (1) **Next offered 1987-88**
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 (2) HUM-D **Not to be offered 1987-88**
3-0-6

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 Marquez, 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 1987-88**
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: bourgeois women, women rebels, and redefinition of sex roles. Comparative analysis of works by: Laclos, Fontane, Molière, Sor Juana Inés de la Cruz, Zola, Stefan, Lorca, Wolf, Wittig, and Puig. Materials used include films by: Godard, Buñuel, Saura, M. v. Trotta.
I. de Courtivron, M. Resnick

21.299J New Women's Voices

(Same subject as SP 431J)
Prereq.: —
U (1) **Not to be offered 1987-88**
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 women's 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.
I. de Courtivron, E. Waldstein, M. Resnick, M. Richardson

21.300J Courtship Themes in Romance Literature

(Same subject as SP 434J)
Prereq.: —
U (2) HUM-D **Next offered 1987-88**
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 (2) **Next offered 1987-88**
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 (1) **Not to be offered 1987-88**
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, Dostoevski, 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 (2) HUM-D **Not to be offered 1987-88**
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 Twentieth-Century European Drama

Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

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 Proust

Prereq.: —
U (2) **Next offered 1987-88**
3-0-9

Study of the early works and *Remembrance of Things Past*. Emphasizes: transformation of the novelistic form, role of the artist, concept of time, aesthetic views, portrayal of a decaying society, sexual ambivalence, philosophy of love. Students who know French are encouraged to read the works in the original.
R. E. Jones

21.306 The German Cinema

Prereq.: —
U (1) **Not to be offered 1987-88**
4-0-5

Overview of the German film since its beginnings, emphasizing the New German Cinema of the 70s. Weekly screenings. Lectures and discussions deal with technical and aesthetic as well as socio-historical problems. Students keep weekly journal 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) **Next offered 1987-88**
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.
D. Dollenmayer

21.308 Seminar in Kafka

Prereq.: One subject in any literature
U (2)
3-0-6

A thorough study of Kafka's novels, longer stories, microstories, and autobiographical writings. The human condition according to Kafka in the Age of Anxiety and beyond. Followed by a more concentrated study of the Kafka canon and mystique in exegetic terms ranging from theological and philosophical through the more strictly literary to psychological and sociological. Participants write one major paper (20 to 40 pages) and make one oral report. Readings in translation.
M. Dyck

21.309 German Avant-garde Theater

Prereq.: —
U (1)
3-0-6

Innovative practitioners and theorists on the German stage from the turn of the century to the present time. Naturalism, impressionism, expressionism; epic theatre; variously transmuted new forms of comedy and satire; experimental, documentary, and political drama. Hauptmann, Wedekind, Hofmannsthal, Toller, Hasenclever, Kaiser, Sternheim, Brecht, Weiss, Zuckmayer, Frisch, Dürrenmatt, Handke, Hacks, and others. Readings in translation.
M. Dyck

21.310 Masterpieces of Hispanic Culture (New)

Prereq.: —
U (1) HUM-D **Not to be offered 1987-88**
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*, Garcia Marquez's *One Hundred Years of Solitude*, short stories by Borges, Cortazar and Rulfo. 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 Slavic Civilization: Gods, Demons, and the Supernatural
(New)

Prereq.: —
U (2) HUM-D **Not to be offered 1987-88**
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.
E. Semeka

21.315 Russian Short Story
(New)

Prereq.: —
U (1) HUM-D **Not to be offered 1987-88**
3-0-6

The great development of Russian prose from Pushkin's *Tales of Belkin* and "Queen of Spades" through Gogol, Lermontov, Turgenev, Tolstoi, Dostoevski, 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 discussed. Some contrasting genres, such as Turgenev's novel *Rudin* and Pushkin's *Eugene Onegin* are analyzed.
C. V. Chvany

21.317 Russian Novel of the 19th Century

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
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, Dostoévsky. Their relation to Sterne, Byron, Walter Scott. Students with a knowledge of Russian encouraged to read some texts in the original.
K. Pomorska

21.318 Soviet Literature and Moral Issues

Prereq.: —
U (1) **Next offered 1987-88**
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

(21.320)
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
(New)

(Same subject as 24.948J)
Prereq.: Permission of Instructor
G (2)
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
3-0-6

See description under subject 24.900J.
J. W. Harris, W. O'Neil, J. R. Ross, S. Bromberger

21.322J Language and Its Structure

(Same subject as 24.901J)
Prereq.: 21.140J or 24.900J
U (2)
3-0-6

See description under subject 24.901J.
J. W. Harris

21.323 Language in Discourse

Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

Applies methods and insights of contemporary linguistics and related disciplines in analyzing and understanding ordinary uses of language, as well as literary texts. Includes: speech vs writing, functions and styles of language, word meanings and textual cohesion, metaphor in everyday language and in literature, dialogue and narrative, language change and the aging of texts. Examples in English include translations from languages represented in class.
C. V. Chvany

21.324 Workshop in Translation

Prereq.: Permission of Instructor
U (2) **Next offered 1987-88**
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

21.325 English I: English as a Second Language

Prereq.: Placement test or Permission of Instructor
U (1) **Next offered 1987-88**
3-0-6

Review of the fundamental principles of English structure, American pronunciation, and intonation. Vocabulary building, readings, listening comprehension, and conversation skills. Supplemental language laboratory program.
K. Irving

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.
K. Irving

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 culture.
S. Flynn

21.328 English IV

Prereq.: Placement test or Permission of Instructor
U (2)
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.
K. Irving

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

Prereq.: Placement test or Permission of Instructor
U (1)
3-0-6

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.
K. Irving

21.334 Expository Writing II for Undergraduates: English as a Second Language

Prereq.: Placement test or Permission of Instructor
U (1, 2)
3-0-6

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

21.336 Expository Writing for Graduate Students: English as a Second Language

Prereq.: Placement test or Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

Extensive writing assignments in English essays to practice the rhetorical and stylistic patterns under consideration. Topics progress from the basics of sentence structure through transitions and paragraph formation to organization of entire essay. Devotes some attention to other kinds of writing: grant proposals, thesis precis, job applications, and letters.
K. Irving

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 of 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.
C. Sawyer-Lauçanno

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.
C. Sawyer-Lauçanno

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.
C. Sawyer-Lauçanno

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.
C. Sawyer-Lauçanno

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 21.708 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 I: Greece

Prereq.: —
U (1) HUM-D
3-0-6

Political and cultural history of ancient Greece form 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 in ancient and modern historians; textbook.
H. A. T. O. Reiche

21.351 The Ancient World II: Rome

Prereq.: —
U (2) HUM-D
3-0-6

Roman republic in origin, structure, function. Roles of traditionalism, improvisation, Greek humanism. Outer success, yet internal polarization. Manipulation and terror as political instruments. Pompey, Cicero, Caesar, Augustus in ancient and modern perspective. Definitions of triumph and decline. Rostovzeff 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 (1) HUM-D **Next offered 1987-88**
3-0-6

Transitions from late Antiquity to the First Europe," roughly from 300–1000 AD. 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 Middle Ages II

Prereq.: —
U (2) HUM-D
3-0-6

Europe from the Viking-Magyar invasions through the phenomena of expansion 1050–1300: population growth, "agricultural revolution," revival of towns and trade, advent of a merchant class; feudal monarchies, Crusades, rise of universities and the formation of new elites. The civilization of the High Middle Ages treated as an unstable unity.
R. M. Douglas

21.356 History of the Western World I: 1500-1815

Prereq.: —
U (1) HUM-D
3-0-6

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
3-0-6

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

21.360 European Social History in the 19th and 20th 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.
W. B. Watson

21.361 Europe in the 20th Century

Prereq.: —
U (1)
3-0-6

The quest for mass participation in politics as the unifying theme of European history in the period of the two World Wars. The struggle among mass movements organized by labor, the Church, parliamentary parties, and the state itself for dominance in political life. The consequences of runaway inflation and world depression; causes of World War II; mobilization; and the structure of post-war Europe.
W. B. Watson

Special Subjects and Seminars

21.365 The Renaissance in Italy

Prereq.: —
U (1) **Next offered 1987-88**
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.
R. M. Douglas

21.369 Marx, Darwin, and Freud

Prereq.: —
U (1) HUM-D
3-0-6

Historical and critical study, in depth, 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, in intellectual history, in history and philosophy of the cultural sciences, and in social thought.
B. Mazlish

21.370 Anarchism

Prereq.: —
U (2) **Next offered 1987-88**
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 315J)
Prereq.: —
U (2)
3-0-6

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) **Next offered 1987-88**
3-0-6

The French Revolution and the nature of the revolutionary and Napoleonic settlement; the search for stable political institutions down 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 (2) **Next offered 1987-88**
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) on Russian institutions and culture.
R. E. MacMaster

21.376 Imperial and Revolutionary Russia: Culture and Politics

Prereq.: —
U (1) HUM-D
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) HUM-D
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) **Next offered 1987-88**
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 (1)
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)
3-0-9

Bismark, 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 (the destruction of the European Jews) genocide. The Germanies since 1945: culture, politics, economies, society.
R. E. MacMaster

21.383 Revolution in the 20th Century

Prereq.: —
U (2)
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: 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 (New)

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 socio-political, 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)
3-0-6

Applies psychology, especially psychoanalysis, to 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
3-0-6

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.
P. Maier

21.391 American History Since 1865

Prereq.: —
U (2) HUM-D
3-0-6

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. Readings include speeches, novels, plays, and oral histories as well as pertinent historical articles.
S. J. Deutsch

Chronological Series

21.400 Colonial America

Prereq.: —
U (2)
3-0-6

North American History to 1763 with particular attention to the development of society and politics in the British colonies. Topics: 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 writings on the period as well as documents of our time.
P. Maier

21.401 The American Revolution

Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

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)
3-0-6

Examines efforts to establish a new nation, to work out the meaning of republicanism, to fulfill the ideals of equality and freedom, to maintain social order, and to 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 1987-88**
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) **Next offered 1987-88**
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: 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.
M. E. McGerr

21.405 America in the Twenties and Thirties, 1917-1941

Prereq.: —
U (1)
3-0-6

American politics, society, and culture during World War I, the 1920s, and the Great Depression. Topics: impact of the war on American society; changing gender roles, race and ethnicity; economy and culture of the twenties; 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: 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.
M. E. McGerr

Topical Series

21.409 American Ideas and Culture: From the Puritans to the Civil War

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

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

21.410 American Ideas and Culture: From the Civil War to WWI

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

American intellectual and cultural life in an era of intense social and economic dislocation, studied mainly through the ideas of major figures and movements of the period. "Victorian" culture in the Gilded Age; the influence of Darwin and Freud on American thought; the response of religion to science and the new urban-industrial culture; "Progressive" ideas about reform, class, social order, and justice; changing ideas about race, women, black Americans, the immigrant; developments in literature, art, architecture, and popular culture.
A. D. Kaledin

21.411 American Ideas and Culture: The Modern Age, 1920-1980

Prereq.: —
U (2) HUM-D
3-0-6

American thought and culture from the Jazz Age and the "Lost Generation" of the 1920s through the counterculture of the 60s and the neo-conservatism of the 70s. The fundamentalist-modernist conflicts of the 1920s and the 1970s-80s. 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; trends 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)
3-0-6

Includes popular images and uses of the west, the impact of the frontier on gender relations and community formation, the west as a setting for racial and ethnic contact and conflict, and changing Federal policy. Materials include diaries, fiction, and film.
S. J. Deutsch

21.416J American Women's History

(Same subject as SP 420J)
Prereq.: —
U (2) HUM-D
3-0-6

Starting with Pocohantas 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, two movies shown.
S. J. Deutsch

21.418 The Immigrant Experience: Race and Ethnicity in the US, 1880-1980

Prereq.: —
U (1) **Next offered 1987-88**
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.
S. J. Deutsch

21.420 The Vietnam War, 1945-1975 (New)

Prereq.: —
U (1)
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 anti-war movement. Assigments include oral histories, military memoirs, goverment documents, and films.
M. E. McGerr

21.431 Thomas Jefferson and His Age

Prereq.: —
U (1)
3-0-9

Intensive study of the ideas and life of Thomas Jefferson and, through him, of political, intellectual, and cultural issues central to his era. Considerable attention to the ideas of John Adams and Alexander Hamilton, and to the Jeffersonian tradition in the 19th and 20th centuries.
A. D. Kaledin

Special Subjects and Seminars

21.432 Religion in America

Prereq.: —
U (2)
3-0-6

A history of religious life and thought in America, emphasizing the 19th and 20th centuries. Main topics: 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 310J)
Prereq.: —
U (2)
3-0-6

See description under subject STS 310J.
M. R. Smith

21.435 The American Psyche

Prereq.: —
U (2) HUM-D
3-0-6

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: 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

21.449 Introduction to American Studies: American Popular Culture

Prereq.: —
U (2) **Next offered 1987-88**
3-0-9

Introduction to problems and methods in the interdisciplinary study of American culture. Topic 1985-86: 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 pop-cult "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 of Africa

Prereq.: —
U (1) HUM-D
3-0-9

The history of ancient, medieval, early modern, and pre-20th century Africa with close attention to the peopling of the continent, development of culture, development of kingdoms, slave trade, assault by Europe, partition into colonies, beginnings of colonial rule, and nature of the African response.
R. I. Rotberg

21.451J The History of 20th-Century Africa: Nationalism and Nation-Building

(Same subject as 17.551J)
Prereq.: —
U (2) HUM-D
3-0-9

The political development of modern black Africa, concentrating on an examination of colonial rule, African resistance and rebellion, the ultimate struggle for independence, and post-independence politics and readjustments.
R. I. Rotberg

21.452 Comparative African Politics: Crises in Southern Africa

Prereq.: —
U (2)
3-0-6

Political and historical problems of South Africa, Namibia, Zimbabwe, and other countries of southern Africa. 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

21.455J The History and Politics of the Third World Through the Novel

(Same subject as 17.553J)
Prereq.: —
U (1)
3-0-6

Studies history, society, and politics of the black third world through a selected examination of a dozen critical novels. Authors read include Abrahams, Achebe, Armah, Cary, Lamming, Hutchinson, Mulaisho, Naipaul, Ngugi, Oyonyo, Beti, Sembene, Brink, Gordimer, Paton, and Jacobson.
R. I. Rotberg

21.457J Research Seminar in Imperialism and Colonialism

(Same subject as 17.564J)
Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-6

Topics in the economic, social, and cultural bases of imperialism and colonialism, particularly with regard to Africa. Substantial written work expected.
R. I. Rotberg

History of East Asia

21.460 East Asian History: China

Prereq.: —
U (2) HUM-D
3-0-6

History of Chinese civilization from the Shang through the Ch'ing dynasties (1500 BC–1911 AD). Topics: 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
3-0-6

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, 900-1900 A.D.

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 The Chinese Revolution: 1850-1976

Prereq.: —
U (2)
3-0-6

The protracted process of revolutionary upheaval and social transformation in China from the Taiping Rebellion of the 1850s through the death of Mao, paying attention to the interaction of domestic and foreign influences. Includes comparison of Mao's revolutionary practice with theories of revolution, Marxist and non-Marxist.
P. C. Perdue

History of Latin America

21.470 Latin American History

Prereq.: —
U (1)
3-0-6

Survey of Latin America from the Conquest to the present. Analyzes Latin America as a peripheral" area in the global economy; emphasis on relationships between economic, social, and political change, and on the emergence of the authoritarian state. Case studies include Cuba, Mexico, Argentina, Brazil.
P. H. Smith

History of the Middle East

21.480 The Middle East: From the Rise of Islam to World War I

Prereq.: —
U (1) HUM-D
3-0-6

Surveys Middle Eastern history. Part I examines the Classical Age of Islam (600–1300) through themes of Arab expansion and adaptation. Stresses nomadic-urban encounters, sociopolitical institutions, religious sects, cultural-scientific achievements and their transmission to Europe. Part II examines later Islamic states (post 1300), especially the Ottoman Empire and its background, to modern Middle East. Emphasizes Europe's dramatic expansion after 1800 and Middle Eastern responses to the European challenge, including rise of modern nationalisms.
P. S. Khoury

21.481 The Middle East in the 20th Century

Prereq.: —
U (2) HUM-D
3-0-6

Surveys major political, socioeconomic, and cultural changes in the 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 and Soviet influence, radical nationalist and socialist movements, and the growth of modern states and societies after 1945. Concludes with examination of contemporary problems in historical perspective: Arab-Israeli conflict, crisis in Lebanon, oil and regional security, Islamic revivalism, and the Iranian revolution.
P. S. Khoury

21.482J "The Islamic City": History, Culture, and Form

(Same subject as 4.683J)
Prereq.: —
G (1)
3-0-6

See description under subject 4.683J.
P. S. Khoury, Y. Tabbaa

21.483 Nationalism, Imperialism, Revolution: The Middle East

Prereq.: —
U (1) **Next offered 1987-88**
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.
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

21.490 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 Section and secure the Section Head's approval. Normal maximum is 6 units; to count toward the Humanities Requirement, 9 units are required. Nine-unit projects are occasionally approved.
P. Maier

See 21.708 The Bible and 21.709 The Greeks

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) 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

21.501 Understanding Other Peoples

Prereq.: —
U (1) HUM-D
3-0-9

Anthropological understanding is based on extended, first-hand observations of alien ways of life. From readings, films, and their own projects in the Boston area, students sample the challenges of doing fieldwork, the difficulty of overcoming people's tendency to misunderstand one another, and the discipline's theoretical concerns.
J. Howe

21.502 Culture, Nature, and Human Nature

Prereq.: —
U (2) HUM-D
3-0-6

A detailed consideration of anthropology's contributions to key problems and concepts in the social sciences: culture, human nature, values, roles, exchange, function, structuralism, social change, model-building, theory-testing. Emphasis on the social and historical contexts in which these basic ideas have been developed.
J. Howe

21.503 Introduction to Archaeology: Paths to Civilization

Prereq.: —
U (1) HUM-D
3-0-6

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.
F. Wiseman

21.504 Approaches to Archaeology

Prereq.: —
U (2)
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: 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 (1)
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: 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.

Social Anthropology

21.511 Magic, Shamanism, and Witchcraft

Prereq.: —
U (2)
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 1987-88**
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

21.513 Religious Movements and Social Change

Prereq.: —
U (1) HUM-D
3-0-6

New religions and religious movements, the conditions that inspire them, their effect on society. Messianism, apocalypse, revelation, cults, schismatic and unorthodox sects, nativism, revitalization, revivalism. Examples from the US (revivalism, communal sects, cults), from Europe (medieval heresies and messianism), and from third world societies (the Iroquois Handsome Lake Religion, the Ghost Dance, Cargo Cults, military messiahs).
J. Howe

21.514 Communities in Crisis

Prereq.: —
U (2)
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.
J. Wylie

21.521 Central American Society

Prereq.: —
U (2)
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) HUM-D
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

21.524 The Struggle for Indian Identity in the Americas (New)

Prereq.: —
U (1)
3-0-6

While nation-states derive their ligitimacy from each other, ethnic minorities must confront the nations they live in for recognition of their unique identities. Four examples are considered here; the assimilationist policy in the US toward Native American and ethnic groups; the complex Mexican apparatus to deal with its Indians; exclusion from national life of the Guatemalan Indians; and the efforts to achieve an autonomous relationship between the ethnic groups of the Atlantic Coast of Nicaragua and the government.
M. Diskin

21.530J The Contemporary Family

(Same subject as SP 456J)
Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

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. Consult A. Steinberg.

21.532 Language and Culture

Prereq.: Prereq.: —
U (1)
3-0-6

Language is a primary means by which people construct meaningful worlds in which to live — constructions influenced by such factors as ethnicity, class, gender, personality, and political status. Examines how we communicate as social beings both verbally and nonverbally, and such phenomena as multilingualism, linguistic nationalism, and the evolution of pidgins and creoles.
J. Wylie

Technology and Cultural Context

21.533J Autobiography in Science and Engineering

(Same subject as STS 241J)
Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

Examines the meaning life histories have for their authors and the science and engineering communities. Explores the relation between exemplary figures' careers, the more usual career patterns of their colleagues, and unusual careers which are not used as models, such as those of women, minorities, and scientists in the Third World. Students collect individual life histories of MIT graduates.
S. Traweek

21.534J Modern Times

(Same subject as STS 500J)
Prereq.: —
U (2)
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.
J. Wylie

21.535J Camera and Culture

(Same subject as STS 626J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

See description under subject STS 626J.
S. Traweek

21.536J Cross-Cultural Studies of Scientific and Technological Institutions

(Same subject as STS 231J)
Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

See description under subject STS 231J.
S. Traweek

21.540 Technology and Culture

Prereq.: —
U (1) HUM-D
3-0-6

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.
J. Wylie

21.541J The Archaeology of Technology

(Same subject as STS 400J)
Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

Technologies of ancient and pre-industrial societies as revealed by excavation, scientific analysis of artifacts, ethnohistory. Case studies of technologies include cloth production among the Inca, building in Imperial Rome, Iron Age metallurgy of East Africa. Comparisons to illuminate interactions of technologies with cultures; the role played by materials processing, labor organization, and ideology in the development of industries; the formation of technological styles.
H. N. Lechtman

21.542 Culture and the Visual Arts

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

An anthropological perspective on the visual arts focusing on the arts as cultural media and as nonverbal means of social communication and continuity. Material presented in case study format, including visual arts of small-scale, non-Western societies, imperial arts of the Inca and Roman states, and contemporary art of the US.
H. N. Lechtman

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) **Next offered 1987-88**
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 1987-88**
3-0-6

Ancient societies of Mexico and Central America, from the earliest times to the Aztec and Maya in 1500 A.D. 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 (2) **Next offered 1987-88**
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)
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 (1) **Next offered 1987-88**
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 Graeco-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 (1)
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

21.563 People and the Natural World (New)

Prereq.: —
U (1)
3-0-9

Explores the ways that people interact with natural ecosystems. Using current ecological and anthropological models; basic cultural adaptations such as agriculture, medicinal and ceremonial plant collecting, and animal population management are evaluated in terms of their human cost and benefit and their environmental impact. Lectures are complemented by several field trips which illustrate the core concepts.
F. Wiseman

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.

21.581 Mathematics and Computers in Archaeological Data Analysis (New)

Prereq.: Permission of Instructor
G (1, 2)
2-4-3

A year-long graduate lecture and laboratory course on the uses of mathematics, statistics, and computer technology in the management and analysis of archaeological data. Includes file processing, simple programming, statistical packages, basic descriptive statistics, research design and sampling, classification, seriation, spatial analysis, introductions to multivariate methods and to simulation, and uses and misuses of all these approaches for archaeological interpretation and theory building. Consult H. N. Lechtman.

21.582 Materials in Ancient Societies: Metals

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
3-6-3

Scientific analysis of archaeological artifacts help us understand the cultures that produces them. Manufacture and use of metals in ancient or small-scale societies: includes discussion of ores, smelting, alloying, and techniques of casting and working metal. Technological style and artifact design are related to cultural values and social settings. Laboratory sessions focus on metallographic examination and analysis of excavated metal artifacts or ethnographic materials that present interesting technological or cultural problems. Six to eight hours lab work per week.
H. N. Lechtman

Special Topics

21.598 Special Topics in Anthropology/Archaeology

Prereq.: Any two subjects in Anthropology or Archaeology
U (1)
Arr.

21.599 Special Topics in Anthropology/Archaeology

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 Humanities Requirement, 9 units are required. Exceptional 9-unit projects occasionally approved. Consult A. Steinberg.

See 21.708 The Bible and 21.709 The Greeks

Music

The music subjects described below are grouped within five areas: introductory subjects, 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

Prereq.: —
U (1, 2) HUM-D
3-0-6

Enhances the listening experience by developing analytical hearing and an understanding of the major historical styles and genres of Western music. Fundamentals of musical organization and design taught, but emphasis is on the listening experience itself. Major composers and styles examined in historical perspective through selected works. Intended for beginners. A guide to individual instructor's approaches, which vary, is available from Music Section office, 14N-434. Coordinator: J. S. Bamberger

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, C. Von Canon

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.
J. Coppock

21.605 Developing Musical Structures

Prereq.: —
U (2)
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

21.615 Musical Acoustics (Revised Content)

Prereq.: —
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) HUM-D
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.
M. Marks

21.622 Western Music after 1750

Prereq.: Permission of Instructor
U (2) HUM-D
3-0-6

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.
R. Vazquez

21.623 World Music

Prereq.: Permission of Instructor
U (2)
3-0-9

A comparative study of religious, court, theatre, and folk music of Far-Eastern Asia, India, and the Islamic World. It deals with the functions, theory, and practices of music, the role of musicians, and the nature of the instruments in their respective societies.
S. Erdely

21.625 Vivaldi, Bach, and Handel

Prereq.: Permission of Instructor
U (1) HUM-D
3-0-6

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.
R. Vazquez

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.
J. L. Buttrick

21.627 Schubert to Mahler

Prereq.: Permission of Instructor
U (1)
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.
J. L. Buttrick

21.628 Twentieth-Century Music (Revised Content)

Prereq.: —
U (2)
3-0-6

A survey of major work 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.
J. H. Harbison

21.631 Symphonic Music

Prereq.: Permission of Instructor
U (1) HUM-D
3-0-6

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

21.632 Chamber Music (New)

Prereq.: Permission of Instructor
U (1)
3-0-6

A survey of the literature for various single-instrument-per-part combinations of strings, winds, keyboard, and voices. Focus through papers and recordings on history, influences, structure, and changing performance practices. Where possible, live performances in class by students, guests, and MIT Chamber Players.
Staff

21.633 Operas of Mozart, Verdi, Wagner (New)

Prereq.: —
U (2) **Next offered 1987-88**
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

First half a chronological survey of musical style in American and European films up to the 1960s. Second half a series of interrelated topics: theories of film music, musicals, documentaries, experimental films, recent decades, and the relationship of film music to opera and ballet. Listening and reading assignments, weekly screenings. No musical background necessary, but score-reading ability helpful.
M. Marks

21.635 American Music

Prereq.: Permission of Instructor
U (1) HUM-D **Next offered 1987-88**
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.: Permission of Instructor
U (1, 2) HUM-D
3-0-6

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

21.637 Traditional Music in America

Prereq.: 21.601 or 21.602
U (2) HUM-D **Next offered 1987-88**
3-0-6

A study of the four branches of American musical tradition; the Amero-Indian, the Anglo-Spanish-French American, the Black American, and the diverse ethnic traditions. Emphasis on historical and broad cultural significance of this repertoire. Permission of instructor required.
S. Erdely

Theory/Composition

21.641 Harmony and Counterpoint I

Prereq.: 21.601 or 21.602
U (1, 2)
3-3-6

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.
E. Cohen, J. Coppock

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, 2)
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.
E. Cohen

21.644 Advanced Writing

Prereq.: 21.643
G (1, 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 (Revised Content)

Prereq.: 21.641
U (1)
3-0-6

21.646 Advanced Musical Analysis (Revised Content)

Prereq.: 21.641
G (1)
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

21.649 Musicianship for Performers

Prereq.: —
U (2)
3-3-3

For intermediate and advanced instrumentalists and singers. Trains students to understand, by ear, basic organizing features of music from Bach to Brahms, with the aim of producing more musical playing. Includes intensive sightsinging and score-reading, tonal theory taught by ear, introduction to performance practice tradition, and in-class performance projects. No prerequisite, by audition.
J. Coppock

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)
2-2-2

21.652 Vocal Repertoire and Performance

Prereq.: —
G (1, 2)
2-2-2

For the young singer interested in the study and performance of the vocal literature with special attention to diction and literary skills, and vocal technique. Each term includes music in one foreign language (e.g., German, French) as well as in English. Membership in the MIT Choral Society (without credit) is required. May be repeated for additional credit. Entrance by auditon.
J. Oliver

21.653 MIT Choral Society & Chamber Chorus (Revised Content and Unit)

Prereq.: —
U (1, 2)
4-0-2

An option available to students in the MIT Choral Society who are also members of the Chamber Chorus. Rehearsals for the Chamber Chorus immediately precede those of the Choral Society. Each term covers music from a different period. 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, J. L. Buttrick

21.657 MIT Symphony (Revised Content)

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 Office.
M. A. Thompson

Seminars/Tutorials

21.661 Beethoven

Prereq.: 21.642
G (1)
3-0-6

For students with a basic knowledge of harmony, counterpoint, and score reading. Background in serious instrumental study also desirable. Examines the evolution of Beethoven's thematic, harmonic, and structural style through a close study of his works. Looks at how he was viewed by his contemporaries, and at the changing comprehension of his music in the past 175 years. Readings, class and concert performances, both student and professional.
J. L. Buttrick

21.668J Cognitive Aspects of Musical Development and Learning (A)

(Same subject as 4.946J)
Prereq.: Permission of Instructor
G (1)
3-6-3

Studies of cognitive processes involved in development of musical understanding and performance. How do untrained musical intuitions differ from and develop into those of musical experts. What factors might influence this process — sensory/action know-how, symbolic know-how (graphic, standard, and computer notations)? Research findings applied to close study of compositions. Readings: Piaget, Wertheimer, Wittgenstein; Schoenberg, Lerdahl-Jackendoff, Rameau, Seashore. Individual research projects.
J. S. Bamberger, S. A. Papert

21.671 Digital Music Processing (A)

Prereq.: 21.642, 21.615
G (1)
3-4-5

Digital audio processing as an artistic music production tool. Analysis, resynthesis of musical instrument tones. Nonlinear and linear-predictive synthesis. Perceptually based synthesis using the auditory transform. Digital recording, processing, editing. Digital

reverberation, ambiance control. Music-encoding languages, procedurally defined scores, performer-like interpretation. Real-time synthesis on array processors under gestural control. Human-machine interaction in music performance. Assignments, synthesis projects.
B. L. Vercoe

21.672 Writing for Computer Performance (A)

Prereq.: 21.643, 21.671
G (2)
3-6-3

For those whose writing of music reaches a point where they can exploit digital audio as a new performance medium. Continues audio processing techniques, for realizing an original composition by end of term. Examines representative works, and stylistic relation between instrumental and electronic writing. Methods of integrating these media, as found in works of Davidovsky and Boulez. Directed composition of an original computer-synthesized work, and preparation for its performance in an end-of-term public concert.
B. L. Vercoe

21.681 Music Composition (A)

Prereq.: 21.644
G (1, 2)
3-0-9

Directed composition of larger forms of original writing involving 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 work in progress. Students expected to produce at least one substantive work, performed in public, by the end of the term. Open to qualified undergraduates. May be repeated for credit.
Staff

21.682 Computer Music Composition (A)

Prereq.: 21.672
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, performed in public, by the end of the term. Open to qualified undergraduates. May be repeated for credit.
B. L. Vercoe

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: Performance

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 21.214, 21.218, 21.237, 21.250, 21.288, 21.306, 21.309 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.
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

Prereq.: —
U (1)
3-0-6

Lectures and tutorial discussions cover the areas of lighting design, set design, costuming, make-up, properties, theatre sound, and elements of acting and directing. Each class member undertakes two projects in the fall schedule of Dramashop's one-act productions under the supervision of a member of the Drama Program staff. Written reports, interpretation of the plays, and reviews of outside performances supplement the practical theatre work. Satisfies the practicum requirement of a Drama concentration.
R. N. Scanlan

21.703 Performance Workshop in Drama

Prereq.: 21.702
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 Performance Workshop in Dance

Prereq.: —
U (1, 2)
3-4-2

Focuses on modern dance theory, technique, and improvisation composition. Combines study of dance aesthetics with studio work to introduce students to the variety of contemporary dance. Improvisation composition sessions acquaint students with their own movement vocabularies and develop improvisational exercises into specific choreographic assignments, some of which are included in informal performances at the end of each term. Relevant readings assigned; one paper required.
B. Soll

21.705 Special Topics in Drama

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

Traditions and Texts

Traditions and Texts is a special interdisciplinary program of humanities subjects. Each subject involves the close examination of original texts, intensive classroom discussion, and the writing of analytical papers. The Bible (21.708) and The Greeks (21.709) are considered foundation subjects. It is recommended that one or both of them be taken before other subjects in this program.

21.708 The Bible

Prereq.: —
U (1, 2) HUM-D
3-0-6

An introduction to major Biblical texts including Genesis, Exodus, Job, the prophetic and historic books of the Old Testament, the Gospels and Epistles. Stresses the place of the Bible as foundation-text for central religious, political, sexual, and ethical ideas in Western culture. Comparative readings in related traditions (Canaanite, Egyptian, Gnostic). Examination of selected instances of the Biblical tradition in later art, music, literature.
Term 1: *T. Merritt*
Term 2: *T. Merritt, A. Steinberg*

21.709 The Greeks

Prereq.: —
U (1, 2) HUM-D
3-0-6

Close study, through translations, of major ancient Greek texts: *Iliad* or *Odyssey,* tragedy and comedy, history, philosophy. Focus on the historically changing perceptions of human excellence, justice, and the locus, individual and/or collective, of human salvation — if any. Collateral attention to standards of beauty embodied in Greek art and architecture (slides and Boston Museum of Fine Arts).
Term 1: *H. A. T. O. Reiche*
Term 2: *A. Kibel*

21.714 The Renaissance and Reformation

Prereq.: —
U (2) HUM-D
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

21.717 The Modern Period: 1900-1970

Prereq.: —
U (2) HUM-D
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: Dinesen, Breton, Gropius, Marinetti, Gide, Proust, Pirandello, Jung, Giraudoux, O'Neill, Joyce, Eliot, Kafka, Malraux, Brecht, Beckett, Lawrence, Lessing, and Solzhenitsyn.
R. E. Jones

21.718 The Americans

Prereq.: —
U (1) HUM-D
3-0-9

Major themes of the American imagination as revealed in American literature, historical writing, and American art from the 17th century through the 19th century. The development of American identity and mythology. Ideas about the land, nature, purpose, the Indian, society and the individual, freedom and community. Among authors read: Bradford and other Puritans, Edwards, Jefferson, Franklin, Crevecoeur, Emerson, Cooper, Whitman, Parkman, Henry Adams. Among artists viewed: Copley, Allston, Cole and other 19th-century landscape painters, Eakins, and Homer.
A. D. Kaledin

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)
3-0-6

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, M. Richardson, Staff

21.731 Writing and Experience

Prereq.: —
U (1, 2)
3-0-6

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)
3-0-6

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.
Staff

21.734 The Elements of Style

Prereq.: —
U (1, 2)
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.
H. Ritvo

Intermediate

21.735 Writing and Reading the Essay

Prereq.: —
U (1, 2) HUM-D
3-0-9

Examination of how to write formal and informal essays. Extensive practice in composition, revision, and editing; wide reading in the literature of the essay form from the Renaissance to the present. Discussion-workshop class style: weekly discussion of student work; study of examples from published works; frequent conferences.
B. Avishai, M. Richardson

21.738 Words

Prereq.: —
U (2)
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)
3-0-6

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; 2)the problems of reality and fiction in autobiography and biography. Students write in either or in both modes.
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.
B. Avishai, H. Ritvo

Creative Writing

Introductory

See subject 21.731.

Intermediate

21.755 Writing and Reading Short Stories

Prereq.: —
U (1, 2) HUM-D
3-0-6

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.
R. Becker, J. Hospital, F. Howe, 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 of work of professional writers.
I. Karmel

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
3-0-6

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.
R. Becker, K. Kumin

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 her or his 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 (2)
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
3-0-6

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 semi-technical subject required.
M. LaFollette, 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 semi-technical 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.
R. Goodell

Advanced

21.783 Science and Technical Writing Workshop (Revised Content and Unit)

Prereq.: 21.782
U (1)
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.
R. Goodell, M. LaFollette

21.790 Naturalist Writing

Prereq.: —
U (1)
3-0-6

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 semi-technical subjects.
J. Paradis

21.792 Science and Technical Writing Internship

Prereq.: 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.
R. Goodell

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. Manning

See 21.708 The Bible

Interdisciplinary Subjects

21.901J Reading Seminar in Humanities, Science, and Technology I

(Same subject as STS 130J)
Prereq.: —
U (1)
2-0-7

21.902J Reading Seminar in Humanities, Science, and Technology II

(Same subject as STS 131J)
Prereq.: —
U (2)
2-0-7

See description under subjects STS 130J, STS 131J.
Staff

21.903J Project Seminar on the Context of Research

(Same subject as STS 132J)
Prereq.: —
U (1, 2)
3-0-6

See description under subject STS 132J.
L. Trilling

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 1987-88**
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 (Revised Content)

Prereq.: Permission of Instructor
U (2) **Not to be offered 1987-88**
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, L. Kampf

21.930J Ancient Cosmology

(Same subject as STS 223J)
Prereq.: —
U (2) HUM-D
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 literary 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.
T. R. Merritt

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
Traditions and Texts

22 Nuclear Engineering

Undergraduate Subjects

22.UR Undergraduate Research Opportunities Program

Prereq.: —
U (1, 2)
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.
R. K. Lester, 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

22.010 Seminar in Nuclear Engineering

(22.001)
Prereq.: —
U (1)
2-0-4

Surveys the range of topics covered by the Nuclear Engineering 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 discussed by guest lecturers from the appropriate discipline. A demonstration of the MIT Reactor as a research tool is given.
D. D. Lanning

22.012 Seminar in Fusion and Plasma Physics (New)

Prereq.: —
U (1)
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 (New)

Prereq.: —
U (2)
2-0-4

Seminar explores a wide range of topics in radiation effects and uses, some involving state of the art experimental techniques, others making use of unique laboratory facilities or novel computer simulation programs, and each is a current area of teaching or research for one or more faculty members. Most lectures are accompanied by laboratory demonstrations.
A. C. Nelson, R. G. Ballinger, G. L. Brownell, S-H Chen, O. K. Harling, K. C. Russell, S. Yip

22.02 Introduction to Applied Nuclear Physics

Prereq.: 8.02, 18.02
U (1) SD
3-0-9

Introduces nuclear physics emphasizing those aspects which 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 covering 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 relation 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.
L. M. Lidsky, K. F. Hansen

22.03 Engineering Design of Nuclear Power Systems

Prereq.: —
U (1) SD
3-0-9

Introduces nuclear engineering 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.
K. F. Hansen

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.
M. K. Kazimi, N. E. Todreas

22.032 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.
M. W. Golay

22.04 Radiation Effects and Uses

Prereq.: —
U (2) SD
2-1-9

Current problems in science, technology, health, and environment which 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.
A. C. Nelson

22.05 Introduction to Engineering Economics

Prereq.: —
U (2)
3-0-9

Introduces methods used by engineers for the economic analyses of alternatives. Time-value-of-money mechanics; present worth and rate-of-return methodology; dealing with depreciation and taxes, inflation, and escalation; levelized cost; replacement and retirement problems. Component cost modeling, economy-of-scale and learning-curve effects. Cost-risk-benefit analysis, insurance, and other probabilistic applications. Examples from many engineering disciplines.
M. J. Driscoll

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, alternate 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 or 3.14 or 22.071J
U (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 22.70J but assignments differ.
R. G. Ballinger

22.071J Physical Metallurgy Principles for Engineers

(Same subject as 3.071J)
Prereq.: 3.091
U (1)
3-0-9

Thermodynamics and stability of alloy phases. Diffusion-controlled rate processes. Defect properties and mechanical properties. Emphasizes structural evolution, structure-property relations, and the common features among various materials. Introduces quantitative analysis in physical metallurgy for engineering materials. Meets with 22.71J, but assignments differ.
A. Mortensen

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. 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)
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) HASS
3-1-8

See description under subject 2.18J.
D. D. Lanning, T. B. Sheridan, A. Hein

22.09 Introductory Nuclear Measurements Laboratory

Prereq.: 22.02
U (2) LAB
2-6-4

Basic principles of interaction of nuclear radiation with matter. Statistical methods of data analysis; introduction to electronics in nuclear instrumentation; counting experiments using Geiger-Muller counter, gas filled proportional counter, scintillation counter, and semiconductor detectors. Eight experiments are performed which include applications to health physics, neutron activation analysis, neutron diffraction, reactor physics, and reactor technology. Meets with 22.29, but assignments differ.
N. C. Rasmussen

22.091 Special Topics in Nuclear Engineering

Prereq.: —
U (1, 2, S)
Arr.

For undergraduates who desire to carry out 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)
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

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.
A. C. Nelson, E. P. Gyftopoulos

22.113 Nuclear and Atomic Collision Phenomena (A) (New)

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. Yip

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.
L. M. Lidsky, K. F. Hansen

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, poisons, depletion phenomena, and elementary neutron kinetics. Attention directed to the application of reactor theory to actual reactor systems.
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

22.29 Nuclear Measurements Laboratory (A)

Prereq.: *22.211*
G (2)
2-6-4

Basic principles of interaction of nuclear radiations with matter. Principles and methods for detection and energy determination of gamma rays, neutrons and charged particles. Experiments on gas-filled, scintillation, and semiconductor detectors: nuclear electronics such as pulse amplifiers, multichannel analyzers, and coincidence techniques: applications to neutron activation analysis. X-ray fluorescence analysis, neutron diffraction, and radiation dosimetry. Meets with 22.09, but assigments differ.
N. C. Rasmussen

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. W. Golay

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.
M. S. Kazimi, N. E. Todreas

22.313 Advanced Engineering of Nuclear Reactors (A)

Prereq.: *22.212*, 22.312
G (2)
3-0-9

Advanced topics in nuclear engineering emphasizing thermo-fluid dynamic design methods and criteria for thermal limits of various reactor types. Fundamentals of transient heat transfer and fluid flow under operational and accidental conditions. Detailed analysis of fluid flow and heat transfer in complex geometries.
M. S. Kazimi

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: 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.
J. E. Meyer, O. Buyukozturk

22.32 Nuclear Power Reactors (A)

Prereq.: 22.211, 22.312
G (2)
3-0-9

A descriptive survey of 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, fast reactors both liquid-metal and gas-cooled, and the molten salt breeder reactors. Compares reactor characteristics both in class and by individual student projects. Discusses development problems and assesses potentials for future improvements.
L. M. Lidsky

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 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 22.033, but assignments differ.
M. W. Golay

22.341 Nuclear Energy Economics and Policy Analysis (A)

Prereq.: Permission of Instructor
G (1)
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

22.35 Nuclear Fuel Management (A)

Prereq.: 22.211
G (2)
3-0-9

Principles of physics and engineering governing and constraining the configuration, arrangement, and time-dependent behavior of fuel for nuclear reactors, emphasizing 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 1987-88**
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.
N. E. Todreas, P. Griffith, W. M. Rohsenow

22.37 Environmental Impacts of Electricity (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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. Siu

22.39 Nuclear Reactor Operations and Safety (A)

Prereq.: 22.211, 22.311
G (2) **Not to be offered 1987-88**
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, 1.143J or 13.622J
G (2)
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. Siu, E. G. Frankel

Numerical and Mathematical Methods

22.41 Numerical Methods of Radiation Transport (A)

Prereq.: 18.076, 22.212
G (2) **Next offered 1987-88**
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. Applications emphasized through assignments requiring use of computer.
A. L. Schor

22.43 Advanced Numerical Methods in Engineering Analysis (A)

Prereq.: 22.42
G (1) **Not to be offered 1987-88**
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.
A. L. Schor

22.44 Computational Methods in Materials Science and Engineering (A)

Prereq.: —
G (2) **Next offered 1987-88**
3-0-9

Principles and applications of methods for computing materials properties and behavior. Atomistic simulation techniques of molecular statics, molecular dynamics, and Monte Carlo as applied to crystalline solids with and without defects. Continuum modeling of fluid flow phenomena in materials processing. Finite element methods. Statistical techniques of error propagation and multivariate error analysis in experimental design. Hands-on experience using existing computer programs and programs developed during the term. Suitable for advanced undergraduates.
S. Yip, G. Kalonji

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

22.55J Biological and Medical Applications of Radiation and Radioisotopes (A)

(Same subject as HST 560J)
Prereq.: 8.272 or 22.111
G (1)
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.
G. L. Brownell, 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. Quantitation of images and reconstruction algorithms. A comprehensive term paper required.
G. L. Brownell, A. C. Nelson, P. P. Lele, Staff

22.561J Magnetic Resonance — Analytic, Biochemical, and Imaging Techniques (A) (New)

(Same subject as HST 584J)
Prereq.: Permission of Instructor
G (2)
3-0-12

See description under subject HST 584J.
B. Rosen, S. L. Tan

22.57J Radiation Biophysics (A)

(Same subject as HST 568J)
Prereq.: 8.272 or 22.111
G (1) **Next offered 1987-88**
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.
A. C. Nelson

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, G. P. Beretta

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, G. P. Beretta

22.58 Principles and Practice of Radiation Measurement and Protection (A)

Prereq.: 22.111
G (2)
2-4-6

Combines lecture, demonstration, and experiment. Covers effects of radiation on persons, and control of radiation exposure including applicable standards and the measurement of radiation. Real experience in radiation, use, measurement, management, and control provided at the MITR, a linear accelerator, and power reactors. Covers theory and use of α, β, γ, and *n* detectors and spectrometers. Covers preparation and handling of isotopes, shielding, analysis, and design of radiation protection systems and procedures, in applications including nuclear power generation, medical, and research uses of radiation.
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. Friedberg

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, alternate 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 8.08, 18.04 or *18.075*
G (1)
3-0-9

See description under subject 8.613J.
K. Molvig, 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, A. Bers, R. C. Davidson

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. R. Parker

22.616 MHD Theory of Magnetic Fusion Systems II (A)

Prereq.: 6.653J or 22.615J
G (2) **Next offered 1987-88**
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, non-axisymmetric and tandem mirrors.
J. P. Freidberg

22.63 Engineering Principles for Fusion Reactors

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
3-0-9

Introductory subject for advanced undergraduate and graduate students. Vacuum engineering based on considerations of free molecular flow, surface physics and standard design practices, magnetic field generation by normal cryogenic and superconducting coils, high voltage engineering and practice, production of high power ion, electron and neutral beam systems, microwave engineering for plasma systems, applications to fusion systems. Open to qualified undergraduates.
D. R. Cohn, J. E. Meyer

22.64J Plasma Kinetic Theory (A)

(Same subject as 8.621J)
Prereq.: 8.613J or 16.59J
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 (1) **Not to be offered 1987-88**
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, K. Molvig

22.67 Principles of Plasma Diagnostics (A)

Prereq.: 22.611J or 6.651J or 8.613J
G (1) **Not to be offered 1987-88**
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.: 22.71J or 3.71J or 3.14
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 Principles for Engineers (A)

(Same subject as 3.71J)
Prereq.: Permission of Instructor
G (1)
3-0-9

Thermodynamics and stability of alloy phases. Diffusion-controlled rate processes. Defect properties and mechanical properties. Emphasizes structural evolution, structure-property relations, and the common features among various materials. Quantitative analysis in physical metallurgy for engineering materials. Meets with 22.071J, but assignments differ.
A. Mortensen

22.72J Nuclear Fuels (A)

(Same subject as 3.72J)
Prereq.: 3.13 or 3.14 or 22.71J or 3.71J
G (1) **Not to be offered 1987-88**
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.: 3.02 or 3.71J or 22.071J or 22.71J, 22.74J
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)
(New)

(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 (2)
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

An 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 assignments differ.
M. Miller

22.82 Engineering Risk-Benefit Analysis (A)

Prereq.: 18.02
G (2)
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.
D. G. Jansson

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 carry out 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 student requirements.
A. F. Henry

22.911 Seminar in Nuclear Engineering

Prereq.: —
G (1)
2-0-1

22.912 Seminar in Nuclear Engineering

Prereq.: —
G (2)
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 interest.
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)
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

24 Linguistics and Philosophy

Philosophy

24.UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in Linguistics and Philosophy. For further information consult the Departmental Coordinators.
Linguistics: W. O'Neil
Philosophy: N. Block

24.00 Introduction to the Problems of Philosophy

Prereq.: —
U (1, 2) HUM-D
3-0-6

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 on examination and evaluation of proposed solutions to the problems.
S. Bromberger

24.01 Contemporary Moral Issues

Prereq.: —
U (1, 2) HUM-D
3-0-6

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.
J. W. DeCew

24.02 The Meaning of Life

Prereq.: —
U (1) HUM-D
3-0-6

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

24.03 Logic, Language, and Values

Prereq.: —
U (1, 2) HUM-D
3-0-6

Introduction to that part of philosophy that deals with *truth, meaning,* and *proof.* Application of logic and analysis to perennial philosophical problems such as the existence of God, the difference between deduction and induction, the definition of *good,* and validity in reasoning. Fallacies and paradoxes. Readings from such authors as Plato, Locke, Hume, Bertrand Russell, W. V. Quine.
Staff

24.04 Moral and Legal Responsibility

Prereq.: —
U (2) HUM-D **Next offered 1987-88**
3-0-6

Introduces that area of philosophy which deals with what is involved in holding people responsible for what they do and what they cause. Questions: May anyone ever properly be held responsible or at fault for anything? Is freedom of the will necessary for responsibility or blame? What, if anything, is the justification for punishment? Under what conditions should a legal system hold a person liable for the damage he or she causes? Readings include classical and contemporary writings and some selected judicial opinions.
J. J. Thomson

24.05J Nature of Scientific Knowledge

(Same subject as STS 205J)
Prereq.: —
U (2) HUM-D
3-0-6

An introduction to fundamental philosophical problems concerning the nature of science and its development. How, for example, is scientific knowledge arrived at; in what circumstances are theories rejected and replaced; what criteria or values govern these processes; and what gives their outcome such reliability? Are facts given once and for all, independent of theory, or does change of theory change what it is to be a fact? Do scientific theories describe an underlying reality, or do they merely provide an economical systematization of concrete experimental results?
T. Kuhn

24.08 The Human Mind

Prereq.: —
U (1, 2) HUM-D
3-0-6

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?
R. Cummings

24.09J Classics in Political Philosophy

(Same subject as 17.113J)
Prereq.: —
U (2) HUM-D
3-0-6

Introduction to conceptions of social justice through a close study of classical works in the history of political philosophy that present complete and systematic accounts of human nature and just association. Readings: Plato's *Republic,* Hobbes' *Leviathan,* Rousseau's *Social Contract,* and Marx's *German Ideology.*
J. Cohen

24.111 Philosophy of Biology

Prereq.: —
U (1) **Next offered 1987-88**
3-0-9

Introduces methodological and conceptual issues of biology. Topics: creationism: sociobiology; nature vs nurture; whether Mendelian genetics is reducible to molecular biology; teleological explanation in biology; what a species is; the units of selection; the logical status of the principle of natural selection; adaptation and optimization.
N. Block

24.113 Philosophy in Film and Literature (New)

Prereq.: —
U (2)
3-0-9

Study of some major works in each of these 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

24.116J Introduction to Cognitive Science

(Same subject as 9.62J)
Prereq.: —
U (1)
3-0-9

See description under subject 9.62J.
D. N. Osherson

24.119 Minds and Machines

Prereq.: —
U (1, 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.
N. Block

24.121J Feminist Philosophy

(Same subject as SP 410J)
Prereq.: Permission of Instructor
U (2) **Next offered 1987-88**
3-0-6

An introduction to the views of contemporary feminist philosphers on the person, experience, science, moral life, and practice of doing philosophy. Also an examination of selections from classical texts and influential contemporary thinkers from a feminist perspective. Readings from Aristotle, Augustine, Rousseau, de Beauvoir, Frye, Held, and others. Approved for concentration in Women's Studies only.
C. Whitbeck

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 1987-88**
3-0-6

The philosophy of Edmund Husserl. Readings from Logical Investigations, Ideas I, Cartesian Meditations, The Idea of Phenomenology. Discussion centered 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 Socrates and Plato

Prereq.: One Philosophy subject
U (2)
3-0-9

The quest for the historical Socrates; Socratic questions, dialectic, and paradoxes. The philosophy of Plato's middle period, with emphasis on the theory of forms and its bearing on ethics and theory of knowledge. Plato's critical dialogues. Some attention to Socrates' predecessors and to Aristotle.
R. L. Cartwright

24.202 Modern Philosophy: Descartes to Kant

Prereq.: One Philosophy subject
U (1)
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.
J. Hyman

24.203 Aspects of 20th-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

24.210 Problems in the Philosophy of Love (New)

Prereq.: One Philosophy subject
U (2)
3-0-9

Philosophical issues in the study of effective bonding: e.g., the distinction between appraisal and bestowal as types of valuation, the nature of idealization, the development of ego ideals, and the relationship between love, desire, emotion, and reason. Readings in recent philosophy.
I. Singer

24.211 Theory of Knowledge

Prereq.: One Philosophy subject
U (1)
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) **Next offered 1987-88**
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. W. DeCew

24.231 Ethics

Prereq.: One Philosophy subject
U (2)
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.
J. W. DeCew

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

24.235 Philosophy of Law

Prereq.: One Philosophy subject
U (1)
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. W. DeCew

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

24.272J Rise of Scientific Cosmology: Aristotle to Newton

(Same subject as STS 224J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-9

Centering on theories of terrestrial and celestial motion, the subject traces the development of ideas about the physical universe from classical antiquity to the 17th-century foundation of modern science. Readings emphasize selections from the original scientific sources, especially: Aristotle, the Scholastics, Copernicus, Galileo, Descartes, Huyghens, and Newton.
T. S. Kuhn

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.
P. Horwitch

24.410 Topics in the History of Philosophy (A)

Prereq.: Permission of Instructor
G (1)
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.
J. Hyman

24.501 Problems in Metaphysics (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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.
J. J. Thomson

24.518J Problems of Mental Representation (A)

(Same subject as 9.671J)
Prereq.: Permission of Instructor
G (2)
3-0-9

Topics: the case for mental representation; doubts about the intelligibility of mental representation; the relation between internal language and external language; where 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.
N. Block

24.601 Topics in Moral Philosophy (A)

Prereq.: Permission of Instructor
G (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. W. DeCew

24.611J Political Philosophy (A)

(Same subject as 17.106J)
Prereq.: Permission of Instructor
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.
J. Cohen

24.703 Set Theory (A)

Prereq.: 24.241
G (1) **Next offered 1987-88**
3-0-9

Zermelo-Fraenkel set theory. Topics: the paradoxes and their resolutions, relations, functions, orderings, ordinals, the reduction" of arithmetic to set theory, types and the general structure of the universe of set theory, cardinals, orders of infinity, continuum question, Konig's theorem, concept of truth, Lowenheim-Skolem theorem, reflection principle, measurable and inaccessible cardinals, constructibility, and forcing.
G. S. Boolos

24.711 Topics in Philosophical Logic (A)

Prereq.: Permission of Instructor
G (1)
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.
R. L. Cartwright

24.715 Intentionality and Logic (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-0-9

Formal systems and philosophical perspectives on the analysis of modality and intentional discourse (propositional attitudes). Elements and evolution of modal and intensional logic; criticisms and comparisons with other systems. Topics and reading given special emphasis and may vary from year to year.
J. Higginbotham

24.801 Philosophy of Mathematics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

Examination of major philosophies of mathematics — logicism, formalism, intuitionism — on the nature of mathematical proof, existence of mathematical entities, and related issues. It is strongly recommended that students have taken 24.241 or equivalent.
G. S. Boolos

24.810 Topics in Philosophy of Science (A) (New)

Prereq.: Permission of Instructor
G (2)
3-0-9

Topics in the foundations of science, e.g., 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. 1986-87 seminar focuses on concepts of "natural kinds" in their relation to topics above.
S. Bromberger, T. S. 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, 2) HUM-D
3-0-6

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, J. W. Harris, W. O'Neil, R. Larson

24.901J Language and Its Structure

(Same subject as 21.322J)
Prereq.: 24.900J
U (2)
3-0-6

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, K. Hale

24.915 Elements of Linguistic Theory (A)

Prereq.: —
G (1)
3-0-9

Fundamental aspects of major branches of linguistic research: phonology, syntax, semantics, pragmatics. Foundational issues: organization of grammar, interaction of components, relation to psychology and theory of knowledge. Primarily for nonlinguists with a professional interest in linguistics. Undergraduates with permission of instructor only.
J. Higginbotham, S. Bromberger, M. Halle, N. A. Chomsky

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.

24.931 Linguistic Structures: Romance (A)

Prereq.: 24.951, 24.961
G (1)
3-0-9

Topics in the syntax of the Romance languages, with emphasis on the application of modern theory to classical problems of Romance linguistics and the implications of data drawn from the Romance languages for general linguistic theory. Some knowledge of a Romance language required.
R. S. Kayne

24.933 History of the English Language (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-9

Selected topics in the history of English syntax, morphology, and phonology from Old English to the present, formulated within an attempt at a general theory of linguistic change. Some knowledge of Old and Middle English desirable.
W. O'Neil, S. J. Keyser

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

24.943 Studies in American Indian Linguistics (A)

Prereq.: Permission of Instructor
G (1)
3-0-9

24.944 Studies in American Indian Linguistics (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

Detailed examination of specific topics in the structure of an American Indian language, with special emphasis on linguistic problems which bear on the educational concerns of the community in which the language is spoken. Topic varies from term to term and year to year. Subject may be taken repeatedly with permission of instructor. Native command of an American Indian language preferred.
K. L. Hale

24.946 Workshop in Linguistics and Education (A)

Prereq.: Permission of Instructor
G (2)
3-0-9

An exploration of the educational potential of the theoretical study of language in elementary and secondary education, focusing upon the use of linguistic data and problems as a medium for teaching scientific method; design of language-based games, game-like activities, and research projects appropriate for elementary and secondary school years; a consideration of the design of language-based science curricula in bi- and multilingual communities; the relationship between a language-based science curriculum and other areas of general educational concern.
W. O'Neil

24.948J Linquistic Theory and Second Language Acquistion (New)

(Same subject as 21.320J)
Prereq.: Permission of Instructor
G (2)
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

24.951 Introduction to Linguistics I: Syntax (A)

Prereq.: 24.901J
G (1)
3-0-9

Introduction to theories of syntax which underlie 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.
R. S. Kayne

24.956 Introduction to Linguistics IV: Universal Grammar (A)

Prereq.: 24.951
G (1)
3-0-9

The nature of linguistic universals, which make it possible for languages to differ and place limits on these differences. Study of selected problem areas which show 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.
R. S. Kayne

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.
N. A. Chomsky

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.
R. Kayne, R. Larson

24.960 Seminar in Semantics (New)

Prereq.: 24.973
G (2)
3-0-9

This seminar investigates the semantics of natural language tense and its relation to the syntax of inflectional (INFL) elements. Includes tense scope, temporal anaphora and control, interaction with temporal adverbs and modals.
R. K. 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 at MIT.
M. Halle, D. Steriade

24.962 Advanced Phonology (A)

Prereq.: 24.961
G (2)
3-0-9

Continuation of 24.961. Special emphasis on problem solving.
M. Halle, D. Steriade

24.964 Theory of Phonology (A) (Revised Content)

Prereq.: 24.961
G (1)
3-0-9

Review in depth of one of four major topics in modern phonology: distinctive features (1985-87), stress and meter (1987-88), syllable structure (1988-89), tone (1989-90).
D. Steriade, M. Halle

24.965 Morphology (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
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

24.966J Laboratory on the Physiology, Acoustics, and Perception of Speech (A)

(Same subject as 6.542J)
Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
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) **Not to be offered 1987-88**
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 (1)
3-0-9

An intensive group tutorial/seminar for discussion of research being conducted by participants. No auditors are allowed.
D. Steriade

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

24.972 Language and Computation (A)

Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-9

Introduction to the theory of computation, formal languages, and definability, with special emphasis on topics most pertinent to linguistic research. Automata and turing machine, phase-structure and categorical grammars, inductively definable languages, undecidable problems, basic concept of parsing and complexity theory. Consult Department headquarters.

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. Consult Department headquarters.

24.979 Semantic Theory (A)
(New)

Prereq.: Permission of Instructor
G (1)
3-0-9

Seminar on current research in semantics and generative grammer. In addition to reading and discussion, students may present original research. Topics may vary from year to year, those for 1986-87 being the syntax and semantics of thematic structure, anaphora, binding, and control.
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.
W. O'Neil, D. Steriade

24.992 Survey of General Linguistics I

Prereq.: 24.951, 24.961
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 the 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

Some HST subjects start the Wednesday following Labor Day which is before MIT's fall semester commences.

Students wishing to take HST 010-190 must file an application in Room E25-519.

HST 010 Functional Anatomy of Man (A)

Prereq.: Permission of Instructor
G (1)
2-9-10

Lectures, laboratory dissections, and demonstrations designed to provide a thorough grounding in the structure of the human body and in certain of its functions. Intended for undergraduates and graduate students aspiring to careers in vertebrate biology (including physical anthropology), bioengineering, medicine, and other health-related occupations. Enrollment limited.
F. A. Jenkins, Jr., L. Gehrke, W. C. Hayes, Associates

HST 020 Bone and Connective Tissue (A)

Prereq.: Permission of Instructor
G (2)
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.
D. R. Robinson, W. C. Hayes, J. T. Potts, Jr., A. L. Schiller, C. Sledge

HST 030 Human Pathology (A)

Prereq.: 5.42, 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.
H. Goldman, A. K. Abbas, G. R. Dickersin, Associates

HST 040 Mechanisms of Microbial Pathogenesis (A)

Prereq.: 7.01, 7.05
G (1)
3-6-5

Deals with the mechanisms of pathogenesis of fungi, bacteria, mycoplasma, and viruses. Approach polarized towards mechanisms at biochemical and immunological levels without neglecting epidemiology and selected clinical aspects of diseases. Topics selected for intrinsic interest and cover the demonstrated spectrum of pathophysiologic mechanisms. Enrollment limited. Permission of instructor required.
P. Schaffer, J. Mekalanos, Associates

HST 050 Topics in Quantitative Physiology (A)

Prereq.: 8.01, 8.02; 18.01
G (1)
3-0-7

Selected topics illustrating the use and results of a quantitative approach to physiological problems. Items discussed include a) Stochastic processes, applied to genetic mutations, cardiac electrophysiology, strategies of drug administration. b) Diffusive transport of gases in lung and tissues, electro-diffusion of ions and active transport. c) Excitable cell membranes, action potential models of the axon. d) Homeostasis; principles of feedback control systems; case studies. Weekly problem sets.
F. M. H. Villars, R. J. Cohen

HST 060 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.
S. H. Ingbar, W. Kettyle

HST 070 Human Reproductive Biology (A)

Prereq.: 7.01, 7.05
G (2)
2-4-3

Lectures, laboratory sessions, and case dicussions designed to provide the student with a clear understanding of the physiology, endocrinology, and pathology of human reproduction. In addition, designed to involve student in analysis of the wider aspects of reproduction, such as the social and psychological aspects of human sexual behavior, contraception, unwanted pregnancy, and the menopause. Enrollment limited. Permission of instructor required.
H. Klapholz, I. Schiff, C. Millette, Associates

HST 080 Hematology (A)

Prereq.: 7.05
G (2)
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.
W. S. Beck, R. D. Rosenberg, W. H. Churchill

HST 090 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 will be given to congenital, rheumatic, hypertensive, arteriosclerotic, and coronary heart disease. Enrollment: Lectures - open; Laboratory - limited. Permission of instructor required.
W. H. Abelmann, W. Gamble, R. G. Mark, F. J. Schoen

HST 091 Cardiovascular Pathophysiology (A)

Prereq.: 7.01 or 18.01, 18.02
G (2)
3-0-9

Same as HST 090 but without the laboratory.
W. H. Abelmann, W. Gamble, R. G. Mark, F. J. Schoen

HST 100 Respiratory Pathophysiology (A)

Prereq.: 7.01, 7.05, 8.01
G (2)
1-2-5

Lectures, seminars, and labs which cover the development of the lung, its histology and cellular function, 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.
D. C. Shannon, L. Ginns, H. Kazemi, E. Mark, C. A. Hales, J. C. Weaver

HST 110 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 $Na+$, $K+$, $H+$, and water. Included also the pathophysiology of clinical renal disorders such as acute and chronic glomerulonephritis, pyelonephritis and vascular disease. Enrollment limited. Permission of instructor required.
C. Coggins, H. Rennke, L. Fang, J. V. Bonventre

HST 120 Gastroenterology (A)

Prereq.: 7.01, 7.05, 8.01
G (2)
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 pathopysiological 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 by faculty. Enrollment limited. Permission of instructor required.
M. C. Carey, D. Antonioli, R. H. Schapiro, J. R. Wands, J. L. Madara

HST 130J The Human Nervous System: The Neurosciences I (A)

(Same subject as 9.014J, 20.511J)
Prereq.: Permission of Instructor
G (1)
6-3-6

Encompasses: 1) the gross anatomy, internal organization, and fine structure (light- and electron-microscopic) of the mammalian nervous system; 2) the neurophysiology of the visual system and motor system;
3) neuropathology; and neuroendocrinology;
4) neuropathology; and 5) selected subjects in pathophysiology. Includes five clinical demonstrations.
A. M. Graybiel, M. P. Alexander, E. Bizzi, V. Chan-Palay, M. A. Moskowitz, R. A. North, S. Palay, T. Sabin, P. H. Schiller, H. R. Tyler, R. S. Williams, R. J. Wurtman

HST 131 Pathophysiology of the Nervous System (A)

Prereq.: HST 130
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.
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 the students with tutorials and supervision by faculty. Appropriate for students who have had a course in biochemistry and/or molecular biology.
P. M. Gallop, I. M. London, Associates

HST 142 Molecular and Cellular Biology and Immunology (A)

Prereq.: Permission of Instructor
G (1) **Not to be offered 1987-88**
4-0-8

Overview of molecular biology, cell biology, and immunology.
H. N. Eisen, H. F. Lodish, R. C. Mulligan

HST 170 Immunology

Prereq.: 7.05
G (1)
4-0-8

A version of General Immunology 7.73 organized for HST students in the Biomedical Sciences Curriculum.
H. N. Eisen

HST 190 Statistical Planning and Analysis of Biomedical Investigations (A)

Prereq.: Knowledge of calculus
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, chisquare and t-tests, analysis of variance, linear regression, and survival analysis. Case studies include application to diagnostic screening, clinical drug trials, and physiological experiments. Emphasis on experimental studies rather than epidemiology.
H. Feldman

HST 200 Introduction to Clinical Medicine (A)

Prereq.: Permission of Instructor
G (2)
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 presentations 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) (Revised Unit)

Prereq.: HST 010, HST 030, HST 090, HST 100, HST 110, HST 130J, 7.05
G (J)
2-18-6

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, M. Kane, 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)
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 which 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 204 Physical Diagnosis and Introductory Clinical Experience (A)

Prereq.: Permission of Instructor
G (2)
3-0-3

Supplement to HST 200 for students in the M.D. Program. Sessions devoted equally to dermatology, ophthalmology, orthopedic surgery, and otolaryngology.
W. H. Churchill

HST 205 Diagnostic Medicine/Technology Interface (A)

Prereq.: Permission of Instructor
G (J)
3-0-3

Brief introduction to medical decision making and to techniques for evaluation of diagnostic tests. A few diagnostic technologies examined in some depth to show how the strengths and limitations of the technology impact its clinical usefulness. Each student examines one technology in depth and presents his/her findings to the other students. Introduces students to the use of technology in medical decision making. Students learn how to evaluate diagnostic tests, and how to integrate the information from diagnostic tests with clinical data.
J. A. Parker

HST 210 Innovation and Conceptual Design for the Solution of Technical Problems in Clinical Medicine (A)

Prereq.: Permission of Instructor
G (2)
3-0-3

Multidisciplinary approach to technical problem solving in clinical medicine. Case-study approach based on solving real problems in medical engineering and medical physics, with current problems posed by physicians from area hospitals. Problems and proposed solutions presented in seminar setting for evaluation. Generally, it is possible to arrange follow-up of promising conceptual designs outside of class, often as a research topic.
J. C. Weaver, E. G. Cravalho, H. Hechtman, F. J. Schoen

HST 521J Biomedical Transport Phenomena (A)

(Same subject as 10.49J)
Prereq.: 10.301, 10.302
G (2)
2-0-5

See description under subject 10.49J.
C. K. Colton, M. L. Yarmush, 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 1987-88**
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 1987-88**
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; HST 541J
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 applications. 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.: 8.272 or 22.111
G (1)
4-0-8

See description under subject 22.55J.
G. L. Brownell, Staff

HST 561J Principles of Medical Imaging (A)

(Same subject as 2.761J, 22.56J)
Prereq.: Permission of Instructor
G (2)
4-0-8

See description under subject 22.56J.
G. L. Brownell, P. P. Lele, A. C. Nelson, Staff

HST 568J Radiation Biophysics (A)

(Same subject as 22.57J)
Prereq.: 8.272 or 22.111
G (1) **Next offered 1987-88**
4-0-8

See description under subject 22.57J.
A. C. Nelson

HST 570J Biomedical Instrumentation Electronics

(Same subject as 2.781J)
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, R. V. Kenyon, D. Rowell

HST 575J Bioelectronics Project Laboratory (New)

(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 16.356J, 6.555J)
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, R. V. Kenyon, J. M. Teich

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, S. L. Tan

HST 585J Biomedical Measurements (A) (New)

(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

Weekly seminar describing recent research in biomedical engineering, medical physics, and related areas of interest to graduate students with backgrounds in the physical sciences and engineering. Speakers include faculty and research staff from MIT and other institutions in the Boston area, advanced graduate students, and occasional visitors.
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) (New)

Prereq.: —
G (1, 2)
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; to explore active research programs with major biomedical engineering content; and to 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)
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 (1) HASS
3-0-6

See description under subject 14.21J.
J. E. Harris

HST 902 Current Economic and Regulatory Problems in Toxicology (New)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
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) **Next offered 1987-88**
3-0-9

See description under subject 14.286J.
J. E. Harris

HST UR Undergraduate Research in Health Sciences and Technology

Prereq.: —
U (1, 2, S)
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 include MIT faculty members and graduate students; they are assisted by graduate and undergraduate tutors who are interested and committed to the success of the program. An introduction to University 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, seminars, 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

SP290-SP299 ESG Special Topics (New)

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.
J. Y. Lettvin

Integrated Studies Program

SP 351 Integrated Studies Program

Prereq.: —
U (1)
Arr.

SP 352 Integrated Studies Program

Prereq.: —
U (2)
Arr.

A coordinated program for the freshman year which satisfies the General Institute Requirements in physics, chemistry/biology, and mathematics and two Humanities Distribution subjects. Staff includes faculty from the Schools of Science and Engineering and from the Program in Science, Technology, and Society.
L. Trilling

Women's Studies Program

SP 401 Introduction to Women's Studies

Prereq.: —
U (1) HUM-D
3-0-9

An interdisciplinary subject which 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, 3) increase awareness of the history and experience of women as half the world's population.
I. de Courtivron

SP 402J Problems in Cultural Interpretation: Feminist Literary Criticism (New)

(Same subject as 21.177J)
U (2)
3-0-9

See description under 21.177J.
R. Perry

SP 404 Special Topics in Women's Studies (New)

Prereq.: Permission of Instructor
U (1, 2)
3-0-6

SP 405 Special Topics in Women's Studies (New)

Prereq.: Permission of Instructor
G (1)
3-0-6

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.
R. Perry

SP 410J Feminist Philosophy

(Same subject as 24.121J)
Prereq.: Permission of Instructor
U (2) **Next offered 1987-88**
3-0-6

See description under subject 24.121J.
C. Whitbeck

SP 420J American Women's History

(Same subject as 21.416J)
Prereq.: —
U (2) HUM-D
3-0-6

See description under subject 21.416J.
S. J. Deutsch

SP 431J New Women's Voices

(Same subject as 21.299J)
Prereq.: —
U (1) **Not to be offered 1987-88**
3-0-6

See description under subject 21.299J.
M. Resnick

SP 432J Sex Roles in Fiction: Europe and Latin America

(Same subject as 21.297J)
Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-9

See description under subject 21.297J.
E. Waldstein

SP 434J Courtship Themes in Romance Literature

(Same subject as 21.300J)
Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

See description under subject 21.300J.
M. Resnick

SP 436J Women in Literature (New)

(Same subjects as 21.041J)
Prereq.: One subject in literature
U (2)
3-0-6

See description under subject 21.041J.
A. Lang

SP 455J Sex Roles: A Comparative Perspective

(Same subject as 21.531J)
Prereq.: —
U (1)
3-0-9

See description under subject 21.531J.
Staff

SP 456J The Contemporary Family

(Same subject as 21.530J)
Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

See description under subject 21.530J.
J. E. Jackson

SP 460J Psychology of Gender

(Same subject as 9.75J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

SP 461J Psychology of Gender

(Same subject as 9.751J)
Prereq.: Permission of Instructor
G (2) **Next offered 1987-88**
3-0-6

See description under subject 9.751J.
S. E. Carey

SP 474J Virgin, Harlot, Hysteric: Visual Imagery of Women in 19th Century Culture (New)

(Same subject as 4.644J)
Prereq.: —
U (2)
3-0-6

See description under subject 4.644J.
A. Wagner

SP 480J Women and Computers

(Same subject as STS 634J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

See description under subject STS 634J.
S. R. Turkle

SP 482J Gender and Science

(Same subject as STS 450J)
Prereq.: —
U (1)
3-0-6

SP 483J Gender and Science

(Same subject as STS 451J)
Prereq.: Permission of Instructor
G (1)
3-0-6

See description under subject STS 451J.
E. F. Keller

SP 484J Reproductive Biology

(Same Subject as 7.55J)
Prereq.: —
U (2) HASS
3-0-6

See subject description under 7.55J.
N. Hopkins

See also: R. Goldberg's section of 21.003 (Introduction to Fiction: Women's Fiction, HUM-D); and R. Becker's section of 21.755 (Writing and Reading Short Stories).

STS

Science, Technology, and Society

General Subjects

STS UR Undergraduate Research

Prereq.: —
U (1, 2)
Arr.

Undergraduate research opportunities in the STS Program. For further information consult the Departmental Coordinator: P. Buck.

STS 101 The Development of Science and Technology in the 16th to 18th Centuries (New)

Prereq.: —
U (1) HUM-D
3-0-9

History of early development of science and technology, emphasizing their mutual interaction and their role in the intellectual and social history of Western Europe up to the Industrial Revolution. Focuses on major figures such as Galileo, Bacon, Descartes, Newton, and on important technical innovations such as clocks, watches, water wheels, textile machinery, steam engines, and the reasons for consequences of their widespread use. Open only to freshmen enrolled in the Integrated Studies Program.
L. Trilling, M. R. Smith, P. Buck

STS 102 Science, Technology, and Social Change

(STS 100)
Prereq.: —
U (2) HUM-D
3-0-9

An introductory subject designed to help engineering and science students think systematically about the intellectual, moral, and social issues raised by the rapid growth of science and technology in the 20th century. Case studies drawn from current and past experience are used to examine the ways in which cultural, economic, and technical elements in particular situations have shaped opportunities for social choice. Open only to freshmen enrolled in the Integrated Studies Program.
L. Trilling, M. R. Smith, P. Buck

STS 110 Special Topics in Science, Technology, and Society

Prereq.: —
U (1)
Arr.

STS 111 Special Topics in Science, Technology, and Society

Prereq.: —
U (2)
Arr.

For students who wish to pursue special studies or projects with a member of the Program in Science, Technology, and Society.
P. Buck

STS 120 Advanced Topics in Science, Technology, and Society

Prereq.: —
G (1)
Arr.

STS 121 Advanced Topics in Science, Technology, and Society

Prereq.: —
G (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.
P. Buck

STS 130J Reading Seminar in Humanities, Science, and Technology I

(Same subject as 21.901J)
Prereq.: —
U (1)
2-0-7

STS 131J Reading Seminar in Humanities, Science, and Technology II

(Same subject as 21.902J)
Prereq.: —
U (2)
2-0-7

Reading and discussion of major primary and secondary works which illustrate or examine the interactions of science, technology, and society.
Staff

STS 132J Project Seminar on the Context of Research

(Same subject as 21.903J)
Prereq.: —
U (1, 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 or technical development (for example, how a new tool changes the way a phenomenon is analyzed, or how field experience with an engineering system motivates its improvement). A few issues are discussed by the whole group, and students apply the knowledge so acquired to interpret their experience.
L. Trilling

The Social and Historical Study of Science and Technology

STS 200 The Scientific Revolution

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
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 201 History of 19th- and 20th-Century Science

Prereq.: —
U (2) HUM-D **Not to be offered 1987-88**
3-0-9

Survey of the growth of the physical and biological sciences since the end of the Enlightenment. Emphasis on concepts and ideas which had great significance for the development of modern Western culture. Includes: cosmology, mathematical rigor, atomism, field theory, quantum theory, relativity, evolution, genetics.
L. L. Buciarelli

STS 202 Seminar in the History of Science and Technology

Prereq.: —
G (1) **Next offered 1987-88**
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.
L. R. Graham, R. Smith, P. Buck

STS 203 Seminar in the Social Study of Science and Technology

Prereq.: —
G (2)
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, L. L. Bucciarelli

STS 205J Nature of Scientific Knowledge

(Same subject as 24.05J)
Prereq.: —
U (2) HUM-D
3-0-6

See description under subject 24.05J.
T. S. Kuhn

STS 206 Social and Political Implications of Science

Prereq.: —
U (1) **Next offered 1987-88**
2-0-7

STS 207J Social and Political Implications of Science

(Same subject as 17.336J)
Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
2-0-10

Historical and contemporary studies of the interaction of science with social and political values. Examination of 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. Graduate students are expected to write a major research paper.
P. Buck

STS 210 American Science Since the 1930s

Prereq.: —
U (2) HUM-D
3-0-6

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. Focus 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 211 Russian Science and Society

Prereq.: —
U (2)
3-0-6

STS 212J Russian Science and Society

(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. Graduate students are expected to write a major research paper.
L. R. Graham

STS 220 History of Modern Mathematics

Prereq.: 18.02
U (2) **Next offered 1987-88**
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 rigorization of 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

STS 223J Ancient Cosmology

(Same subject as 21.930J)
Prereq.: —
U (2) HUM-D
3-0-6

See description under subject 21.930J.
H. A. T. O. Reiche

STS 224J Rise of Scientific Cosmology: Aristotle to Newton

(Same subject as 24.272J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-9

See description under subject 24.272J.
T. S. Kuhn

STS 231J Cross-Cultural Studies of Scientific and Technological Institutions

(Same subject as 21.536J)
Prereq.: —
U (1) **Next offered 1987-88**
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.
S. Traweek

STS 241J Autobiography in Science and Engineering

(Same subject as 21.533J)
Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

See description under subject 21.533J.
S. Traweek

STS 300 History of Technology in America I: 1787-1876

Prereq.: —
U (1) HUM-D
3-0-6

A study of America's rural, agrarian, and artisanal society from 1787 to the Centennial Exhibition of 1876. Examines the emergence of industrial capitalism within this setting: the rise of the factory system, machinofacture, and new forms of power, transport, and communication. Views technology as part of the larger culture and reveals innovation as a process consisting of a range of possibilities which are chosen or rejected according to social criteria of the time.
M. R. Smith

STS 301 History of Technology in America II: 1876-the Present

Prereq.: —
U (2) HUM-D
3-0-6

The second part of a two-term survey; has the same themes and aims as STS 300. Focus on the maturation of industrial capitalism after 1876 with the emergence of large industrial corporations, national and international markets, and the hallmarks of science-based industry: professional engineers, organized research, and significant institutional integration among schools, laboratories, and workshops.
M. R. Smith

STS 306 The Social and Political Implications of Technology

Prereq.: —
U (2)
2-0-7

STS 307 The Social and Poltical Implications of Technology

Prereq.: —
G (2)
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. Graduate students are expected to write a major research paper.
L. R. Graham, P. Buck

STS 310J Industrialization and Cultural Change in 19th-Century America

(Same subject as 21.433J)
Prereq.: —
U (2)
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. 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.
M. R. Smith

STS 315J The Industrial Revolution: A Social and Cultural History (1750-1850)

(Same subject as 21.371J)
Prereq.: —
U (2)
3-0-6

See description under subject 21.371J.
B. Mazlish

STS 320 Arms, Power, and the Engineer

Prereq.: —
U (1) HUM-D
3-0-6

Examines cultural, social, and technical factors which underlie exercise of political power. Describes how consequences of technical progress and the resulting new outlook transformed selection, style, and goals of the power-elite in England, France, China, and Japan, and how a more effective military technology affected views on war-making and the reach of the state.
L. Trilling

STS 321 Military Enterprise and Technological Change: Historical Perspectives on the American Experience

Prereq.: —
U (1) HUM-D **Next offered 1987-88**
3-0-6

A history of the role of the military in promoting and developing new technology (from medieval times to the present). Examines the design, deployment, and diffusion of new technologies; the behavioral/social problems that arose with their introduction; and their influence on industrialization, colonialism, and warfare in the modern world.
M. R. Smith

STS 400J The Archaeology of Technology

(Same subject as 21.541J)
Prereq.: —
U (1) **Next offered 1987-88**
3-0-6

See description under subject 21.541J.
H. N. Lechtman

STS 405 The Sociology of Science

Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

An introduction and overview of the sociology of science, with special emphasis on the range of theoretical and methodological perspectives in the field, on the sociology of sciences of mind, and on the social controversies around sciences that are experienced as "subversive" of widely shared, "everyday" ways of looking at the world, including artificial intelligence and psychoanalysis.
S. R. Turkle

STS 408 Biotechnology and Society

Prereq.: —
U (1) **Next offered 1987-88**
2-0-7

STS 409 Biotechnology and Society

Prereq.: —
G (1) **Next offered 1987-88**
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 410 Ethical Issues in Science and Engineering

Prereq.: —
U (2)
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 413J Public Controversies on the Control of Technology

(Same subject as 8.206J)
Prereq.: —
U (2) **Next offered 1987-88**
2-0-7

Role of scientists and engineers in anticipating and controlling negative effects of technology. Presentations by individuals who have played major roles in such issues. Historical and current cases studied through readings, discussions, lectures, and student reports. Topics: alternatives to the nuclear arms race; environmental and health hazards; opportunities for involvement and alternative career possibilities.
C. Weiner, B. T. Feld

STS 430J Engineering Design in Social Context

(Same subject as 2.733J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

Examines issues about social values that arise in engineering design. Who influences and what constrains the design process? What is the engineer's role in that process? What are the social implications of design alternatives? Beginning with a study of the design of photovoltaic solar energy systems, the class considers design as an aspect of modern social history, the limits of scientific knowledge in decision making about design, and ethics in the design process.
L. L. Bucciarelli

STS 440J Applied Social Research, Public Policy, and the Social Sciences

(Same subject as 17.818J)
Prereq.: —
G (1) **Next offered 1987-88**
3-0-9

See description under subject 17.818J.
P. Buck

STS 450J Gender and Science

(Same subject as SP 482J)
Prereq.: —
U (1)
3-0-6

STS 451J Gender and Science

(Same subject as SP 483J)
Prereq.: Permission of Instructor
G (1)
3-0-6

Surveys the influence of gender ideology on the development of modern science; especially, its effects on prevailing conceptions of objectivity, the goals of science, and the place of women in science. Explores implications for contemporary scientific practices, methodologies, and research agendas.
E. F. Keller

STS 460J Special Topics in Science, Technology, and Public Policy (A) (New)

(Same subject as 17.306J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 17.306J.
E. B. Skolnikoff, H. Sapolsky, C. Kaysen, P. Buck

Technology and the Organization of Industrial Societies

STS 500J Modern Times

(Same subject as 21.534J)
Prereq.: —
U (2)
3-0-6

See description under subject 21.534J.
J. Wylie

STS 502 The Profession of Engineering

Prereq.: —
U (2) HUM-D
3-0-6

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 9-unit HUM-D subject (lectures, recitations, three full term papers) or as undergraduate seminar (lectures and three short papers).
L. Trilling

STS 510J Politics of Industrialization (A)

(Same subject as 17.154J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 17.154J.
C. F. Sabel

STS 511 Capitalism and Its Critics

Prereq.: —
U (2) HUM-D
3-0-6

The social context and consequences of industrialization and the development of the market economy. The virtues and shortcomings of the market economy as seen by its exponents and critics, examined in the light of its historical development. Early and late industrializing societies compared. Interrelations of market capitalism, technological change, and political evolution.
C. Kaysen

STS 512J Comparative Systems of Industrial Relations and Human Resource Development (A)

(Same subject as 14.674J, 15.674J)
Prereq.: 14.64 or 15.663
G (1)
3-0-6

See description under subject 15.674J.
M. J. Piore

STS 558 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.
R. K. Lester, P. Morrison, G. W. Rathjens, E. Rothschild, J. P. Ruina

STS 575J Problems of Advanced Industrial Societies (A)

(Same subject as 17.166J)
Prereq.: 17.156J
G (2)
3-0-9

See description under subject 17.166J.
S. Berger, M. J. Piore

Cultural Dimensions of Science and Technology

STS 600 Technological Society and Its Critics

Prereq.: —
U (1) HUM-D
3-0-6

The emergence of industrial-technological society has provoked strong critical reactions that affirm the value of a more "natural," simple, emotionally direct and reverential relationship to the environment. These alternative visions are examined in two periods in America: 1) the mid-19th century, and 2) the 1960s. Focuses on the usefulness of these visions as criticism of (or possible alternatives to) the complexity of advanced industrial society.
K. Keniston, L. Marx

STS 601J Literature, Ideology, and National Experience in the US

(Same subject as 21.103J)
Prereq.: —
U (2) HUM-D
3-0-6

Study of the interplay among imaginative literature, the prevailing ideologies, and collective experience in the US, emphasizing critical reading within an 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 602 Perspectives on Technology

Prereq.: —
U (2) HUM-D
3-0-6

A discussion of the centrality of the machine as fact and metaphor, emphasizing its place in theories of technology and society. Reveals how technological power is central to modern thought and policy. Readings include the work of Adam Smith, Thomas Carlyle, Karl Marx, Charles Dickens, Frank Norris, Lewis Mumford, and Jacques Ellul.
L. Marx, M. R. Smith

STS 603 Introduction to Cultural Criticism

Prereq.: Permission of Instructor
U (2)
2-0-7

STS 604 Introduction to Cultural Criticism

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, Emer-

son, 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. Graduate students pursue topics in greater depth.
L. Marx

STS 625J American Television: A Cultural History

(Same subject as 21.032J)
Prereq.: One subject in Literature or Science, Technology, and Society
U (2)
3-0-6

See description under subject 21.032J.
D. Thorburn

STS 626J Camera and Culture

(Same subject as 21.535J)
Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

How photographs come to be produced and read as documentary evidence in science, law, history, anthropology, and families; how photographs and photographic technology shape and are shaped by the cultures in which they are used as a case study in the relations between technology and culture.
S. Traweek

STS 630 Technology and the Individual

Prereq.: —
U (2) **Next offered 1987-88**
3-0-6

How do interactions with technologies and technological systems affect individuals? How do people use technologies for purposes not anticipated by their inventors? Examines the noninstrumental or unintended human effects and uses of technologies through three case studies: computers and intensive users, engineering systems and engineering students, "automated" tools and workers. These cases are used to examine critically theories of "technological man," "technological society," and the effects of technology."
K. Keniston, S. R. Turkle

STS 631 Computers and People

Prereq.: —
U (1) **Next offered 1987-88**
3-3-6

Aspects of the computer presence in our society in the context of larger issues in the sociology of science. Three perspectives on computer impacts examined: 1)Computer impact on large social processes; 2)Computer impact on the individual; 3)Computer impact on sciences of mind and images of humanity. Projects include fieldwork studies at MIT and elsewhere to document and analyze different computer "subcultures."
S. R. Turkle

STS 632 Computer Cultures, Computation, and the Individual (A)

Prereq.: Permission of Instructor
G (1) **Next offered 1987-88**
3-3-6

The computer presence as it affects the individual and contemporary culture. Subcultures of the computer world, computational theories of mind, computer metaphors in the culture, and relationships between people, machines, and programming. Emphasizes ethnographic and individual case study approaches. Each student must undertake a supervised research project.
S. R. Turkle

STS 633J Perspectives on Computers and Society (A)

(Same subject as 6.880J)
Prereq.: Permission of Instructor
G (1)
3-0-9

See description under subject 6.880J.
J. Weizenbaum

STS 634J Women and Computers

(Same subject as SP 480J)
Prereq.: —
U (2) **Next offered 1987-88**
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 home-work."
S. R. Turkle, J. Horwitz

STS 635 The Social Study of Computational Environments Within Universities I (A) (New)

Prereq.: —
G (1)
Arr.

Introduction to a two-semester sequence on the social study of high-density computational environments within university settings. Primarily designed for researchers who are making the study of some aspect of Project Athena the focus of their research. This seminar focuses on study and discussion of Project Athena on MIT as a living and learning enviroment.
S. R. Turkle

STS 636 The Social Study of Computational Environments within Universities II (A) (New)

Prereq.: —
G (2)
Arr.

Advanced topics on the social study of high-density computational environments within university settings. Permission of instructor required for students without STS 635 background. Topics covered depend somewhat on the background and research interest of students enrolled.
S. R. Turkle

SWE

Engineering School-Wide Electives

Undergraduate Subjects

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 558
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.
R. K. Lester, 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)
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 law making — 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 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

Graduate Subjects

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)
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
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 multi-attributed 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.
D. G. Jansson

Technology and Policy TPP

Nuclear Weapons and Arms Control: Technology and Policy Issues

Offered under: 6.932, 13.93, 16.995, 17.486, 22.841
Prereq.: —
G (1)
4-0-8

Reviews nuclear weapons systems developments and efforts at arms control. Focus 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 11J Project Proseminar in Technology and Policy I (A)

(Same subject as 2.981J)
Prereq.: Permission of Instructor
G (1)
4-0-8

TPP 12J Project Proseminar in Technology and Policy II (A)

(Same subject as 2.982J)
Prereq.: TPP 11J
G (2)
4-0-8

Designed to develop the students' ability to analyze problems involving the interaction of technology with economic and social considerations. Case studies and group projects drawn from diverse fields. Integral historical and value-oriented critique of both issues and process. Restricted to graduate students in Technology and Policy; others admitted by permission of instructor.
J. T. Kildow, L. L. Bucciarelli

TPP 13J Engineering Policy Thesis Seminar (A)

(Same subject as 1.980J, 16.783J)
Prereq.: Thesis Registration
G (1, 2)
2-0-1

Seminar designed to assist students in formulating research topics, designing their investigation, executing the analysis, and writing the thesis itself. It thus also serves as preparation for general examinations. Students required to present their work for general discussion by faculty, research staff, and their colleagues.
R. de Neufville, A. R. Odoni

TPP 32J Law, Technology, and Public Policy

(Same subject as 3.576J)
Prereq.: Permission of Instructor
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. C. Caldart

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 written communication skills.
E. J. Scivoletto

AS 111 Leadership Laboratory

Prereq.: —
U (1)
0-1-0

Introduction to the customs, traditions, and courtesies of the Air Force through seminars, guest speakers, and appropriate field trips.
D. L. Loverro

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 contemporay world. Includes Air Reserve Forces and other US Armed Forces. Compares and contrasts US and Soviet military power and capabilities.
E. J. Scivolleto

AS 121 Leadership Laboratory

Prereq.: AS 111
U (2)
0-1-0

Continues AS 111 with emphasis on the role and responsibilities of an Air Force junior officer.
D. L. Loverro

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 is on the doctrine governing the employment of air power and how it developed. Also examines how technology has affected the growth of air power.
S. B. Tubig

AS 211 Leadership Laboratory

Prereq.: AS 121
U (1)
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.
D. L. Loverro

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.
S. B. Tubig

AS 221 Leadership Laboratory

Prereq.: AS 211
U (2)
0-1-0

Continues AS 211. Adds a special program in preparation for Field Training.
D. L. Loverro

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.
R. L. Bliss, N. D. Larson

AS 311 Leadership Laboratory

Prereq.: AS 221
U (1)
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.
D. L. Loverro

AS 32 Management and Leadership

Prereq.: AS 31
U (2)
3-0-3

Continues AS 31 with special emphasis on the basic managerial processes involving decision making, utilization of 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.
R. L. Bliss, N. D. Larson

AS 321 Leadership Laboratory

Prereq.: AS 311
U (2)
0-1-0

Continues AS 311 emphasis on supervisory and leadership skills. Emphasis on advantages of an Air Force career.
D. L. Loverro

[1]Aerospace Studies subjects are not for MIT credit.

M.I.T. ANNUAL CATALOGUES AND BULLETINS
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06
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MS
Military Science[1]

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 which affect policy. Investigates current issues of national security and regional security issues. Emphasis on integration of current events into course topics. Students are asked to challenge current ideas on National Security Policy.
D. L. Loverro, R. G. Hussey

AS 411 Leadership Laboratory

Prereq.: AS 321
U (1)
0-1-0

Exercise of management functions in planning, supervising, and directing cadet corps activities. Acquire proficiency in military leadership skills.
D. L. Loverro

AS 42 Issues For Today's Military

Prereq.: AS 41
U (2)
3-0-3

Study of selected issues which 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.
D. L. Loverro, R. G. Hussey

AS 421 Leadership Laboratory

Prereq.: AS 411
U (2)
0-1-0

Continues AS 411. Includes preparation for professional duties.
D. L. Loverro

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 communication skills.
J. W. Conners

MS 121 The Army Today

Prereq.: MS 111
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. Specialities of soldiers are related to operational unit missions. Introduces principles of war and relates them to actual historical events.
J. W. Conners

MS 21 Instructional Methodology

Prereq.: Permission of Instructor
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.
A. V. K. Blanchard

MS 211 Leadership

Prereq.: MS 111, MS 121
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.
R. J. Kury

MS 221 Branches of the Army

Prereq.: MS 111, MS 121
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.
R. J. Kury

MS 31 Small Unit Tactics

Prereq.: MS 221 or Basic Summer Camp
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.
A. J. Serafini, Jr.

[1]Military Science subjects are not for MIT credit.

MS 311 Military Management

Prereq.: MS 211, 221, or Basic Summer Camp
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.
A. J. Serafini, Jr.

MS 321 Land Navigation

Prereq.: MS 311 or Permission of Instructor
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. T. Yongen

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 and stimulates an interest in the study of military history which leads the potential Army Officer to a mature, informed conception of his 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. J. Kury

MS 411 Military Law and Administration

Prereq.: MS 31, MS 311
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 which 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.: MS 31, MS 321, MS 311
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.
K. L. Callahan

NS 12 Naval Ships Systems I[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.
R. E. Brunson

NS 21 Naval Ships Systems II[2]

Prereq.: 18.02, 8.01
U (1)
3-0-3

Basic system modeling techniques and state variable representations. Examples taken from systems found on naval ships and aircraft. Laser fundamentals, applications, side-looking radar, and radar holography discussed. Selected readings on naval weapons and fire control systems.
R. E. Brunson

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.
K. L. Callahan

[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.

NS 31 Navigation and Naval Operations I[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.
J. P. Wallace

NS 32 Navigation and Naval Operations II

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.
J. P. Wallace

NS 33 Modern Warfare

Prereq.: —
U (1)
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 (Revised Unit)

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.
J. G. Ward

NS 43 Amphibious Warfare

Prereq.: —
U (2)
2-0-2

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

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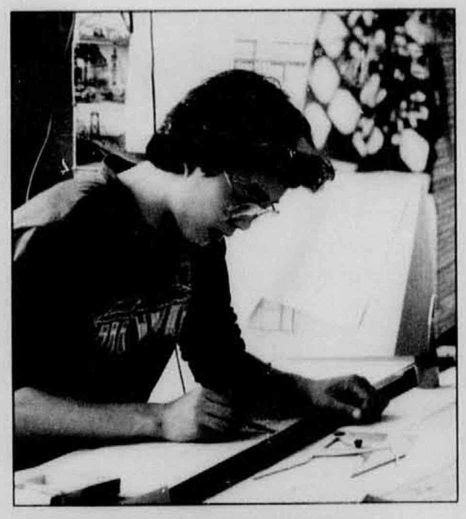

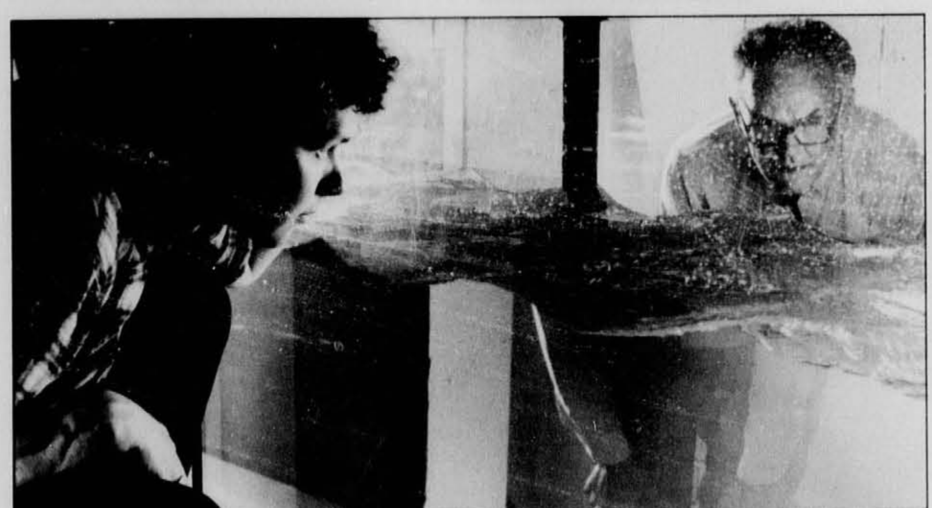

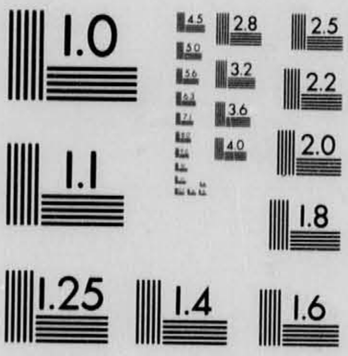

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