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Massachusetts Institute of Technology Bulletin





Massachusetts Institute of Technology Bulletin

THE GENERAL CATALOGUE ISSUE FOR THE YEAR 1961-1962

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

AERONAUTICS AND ASTRONAUTICS

ARCHITECTURE

BIOLOGY

CHEMICAL ENGINEERING

CHEMISTRY

CITY AND REGIONAL PLANNING

CIVIL AND SANITARY ENGINEERING

ECONOMICS AND SOCIAL SCIENCE

ELECTRICAL ENGINEERING

GEOLOGY AND GEOPHYSICS

HUMANITIES

INDUSTRIAL MANAGEMENT

MATHEMATICS

MECHANICAL ENGINEERING

METALLURGY

METEOROLOGY

MODERN LANGUAGES

NAVAL ARCHITECTURE AND MARINE ENGINEERING

NUCLEAR ENGINEERING

NUTRITION, FOOD SCIENCE, AND TECHNOLOGY

PHYSICS

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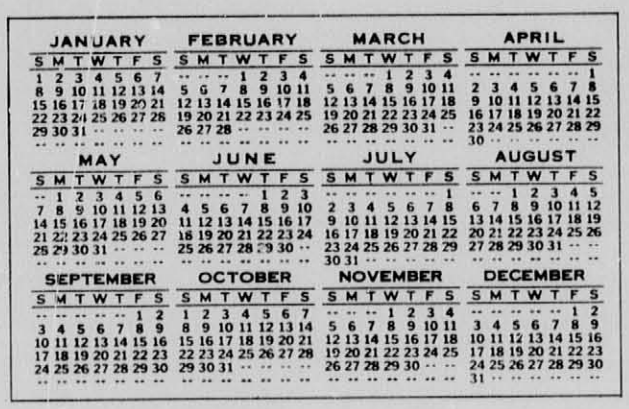
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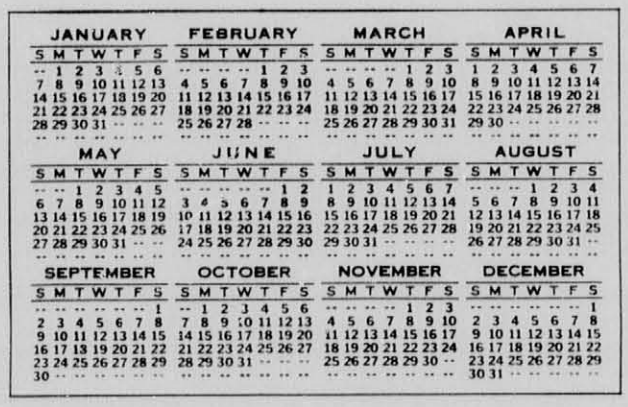
ACADEMIC CALENDAR

1961



SEPTEMBER 14	FIRST TERM BEGINS FOR FRESHMEN
SEPTEMBER 18	FIRST TERM BEGINS FOR UPPERCLASSMEN AND GRADUATE SCHOOL (*Registration Day*)
OCTOBER 12	COLUMBUS DAY (*holiday*)
NOVEMBER 11	VETERANS' DAY (*holiday*)
NOVEMBER 23 *through* NOVEMBER 26	THANKSGIVING VACATION
DECEMBER 21 *through* JANUARY 2	CHRISTMAS VACATION

1962



JANUARY 17	LAST EXERCISES OF THE FIRST TERM
JANUARY 18 *through* JANUARY 20	READING PERIOD
JANUARY 22 *through* JANUARY 26	EXAMINATION PERIOD
FEBRUARY 5	SECOND TERM BEGINS
FEBRUARY 22	WASHINGTON'S BIRTHDAY (*holiday*)
MARCH 26 *through* APRIL 1	SPRING VACATION
APRIL 19	PATRIOTS' DAY (*holiday*)
MAY 22	LAST EXERCISES OF THE SECOND TERM
MAY 23 *through* MAY 25	READING PERIOD
MAY 26 *through* JUNE 1	EXAMINATION PERIOD
MAY 30	MEMORIAL DAY (*holiday*)
JUNE 8	COMMENCEMENT DAY
JUNE 18	SUMMER SESSION 1962 BEGINS
SEPTEMBER 17	FIRST TERM 1962 BEGINS

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[1] Address correspondence to the Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

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[1] Terms expire on June 30 of the year indicated.

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Medical Department

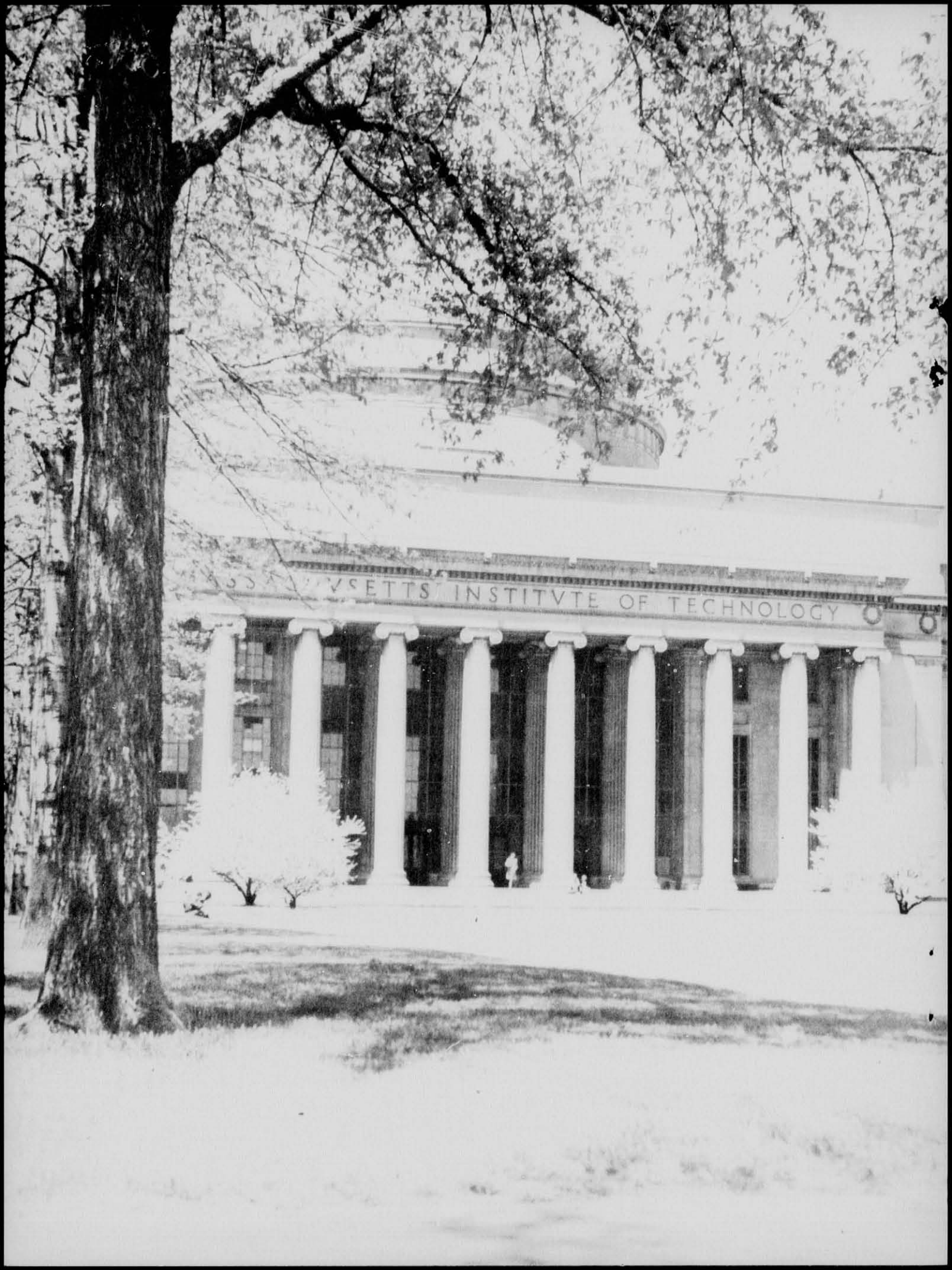
ALBERT OTTO SEELER, M.D.
Head

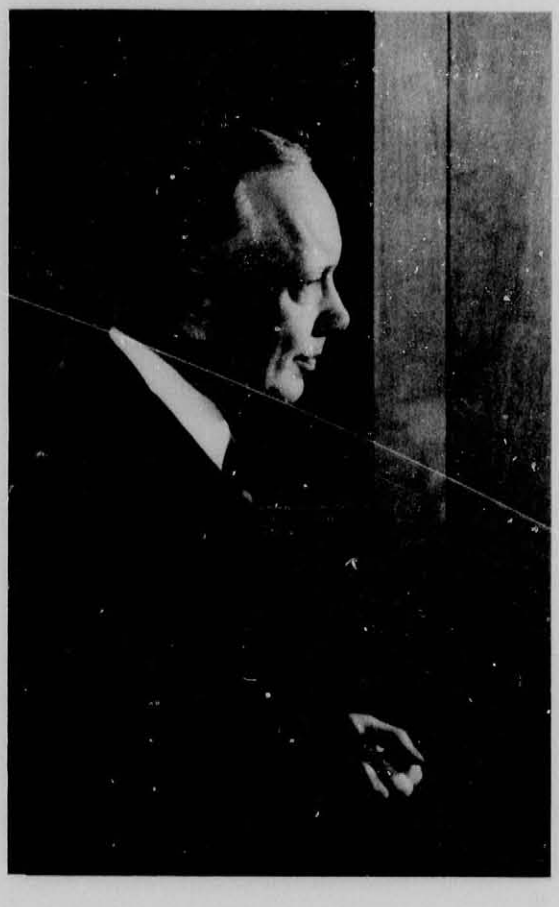
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Department of Naval Science

GEORGE LEVICK STREET, III, B.S.
Captain, U.S. Navy — *Head*


ETTS INSTITVTE OF TECHNOLOGY



To Educate for Leadership

Excerpts from the Inaugural Address by Dr. Julius A. Stratton, eleventh President of the Massachusetts Institute of Technology, June 15, 1959.

This institution was created by William Barton Rogers as an expression of faith in certain new concepts of professional education, and from the very outset our academic policies have been directed by a few central ideas. In essence, Rogers maintained that there is dignity and importance in the mastery of useful knowledge; that the foundations of a professional life may profitably be laid in the undergraduate years, combining with and contributing to a liberal education, to the enrichment of both; and that science and engineering can be the legitimate foundations of a higher education.

M.I.T. has been built upon these convictions. The contributions of our graduates over the years both at home and abroad provide ample proof of their essential worth. The highest goal to which a university may aspire is that its sons and daughters shall be leaders in art and science and that their influence shall be brought powerfully to bear for the welfare of mankind.

Throughout the entire history of the Institute, much of the strength of our educational plan has been derived from the rigor and thoroughness of our method. From the day he enters as a freshman, the undergraduate learns to work in depth and to be held accountable for the results. He learns also to work under pressure and to marshal and employ his knowledge under test. From this discipline and mastery of fundamentals comes an intellectual self-reliance that will stand him in good stead.

But the formal instruction of lectures and classroom is properly only part of the educational process. The intellectual discipline of tests and problems must be supplemented and enlivened by other forces that will arouse and stimulate the impulses of originality latent in every student. We seek to stir our students' imaginations, to encourage them to break free from the channels of conventional thought, and to teach them to bring to bear upon their problems the facts and methods acquired in the classroom.

By its very nature, research demands originality in thought and action; and it is in research that the student as well as the faculty can find an outlet for creative interest and energy and share in the intellectual excitement of new discoveries. University research serves but half its purpose if it becomes remote and isolated from the students themselves.

From his earliest history, man has been driven to build and to do, and the fulfillment of this urge finds its highest expression in the work of the engineer. The engineer is concerned with making and with producing, with converting the yields of pure science to useful products and services. His function is to adapt knowledge to beneficial ends, to find ways and means of solving the practical problems of human existence. There is therefore in the education of the engineer the most compelling reason to develop by all possible means the creative and constructive powers of each student.

* * *

The contributions that the humanities and social sciences have to make to the education of the architect, the scientist, and the engineer have been clearly established. Over the past decade the Institute has won wide recognition for the support that has been given to these more liberal aspects of our curricula.

The range of our professional activities at M.I.T. has for some time been steadily widening. We are concerned not alone with architecture, science, and engineering for their own sake, but increasingly with fields on which these disciplines have a direct impact in contemporary society. In addition to the obviously related fields of management and economics, we are also active in such areas as psychology, political science, international relations, and other social studies.

* * *

M.I.T. is a professional school and as such we have an obligation to impart to our students an understanding of both the privileges and responsibilities inherent in the professional estate. Above and beyond all technical competence, the truly professional man must be

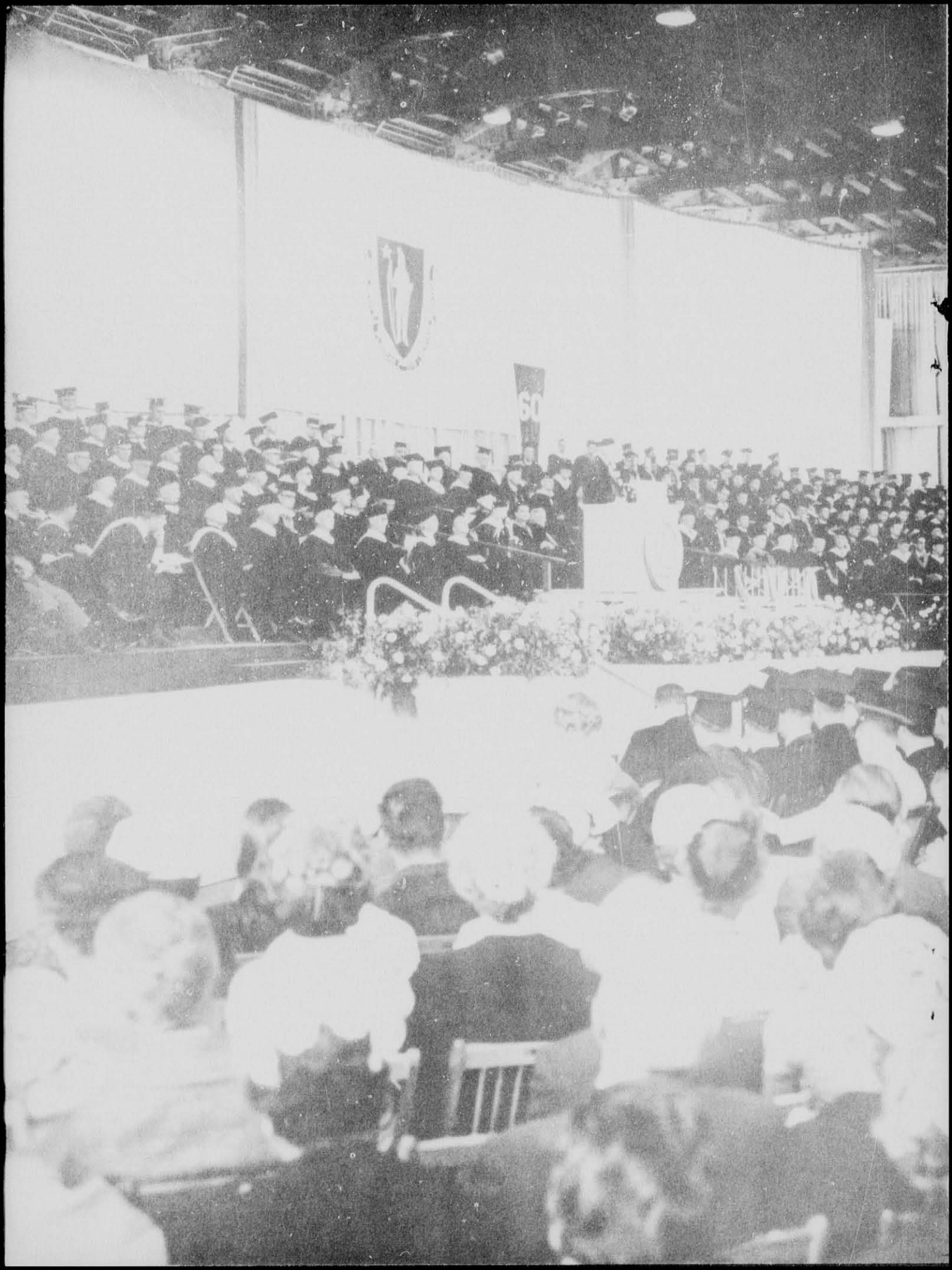
imbued with a sense of responsibility to employer and client, a high code of personal ethics, and a feeling of obligation to contribute to the public good.

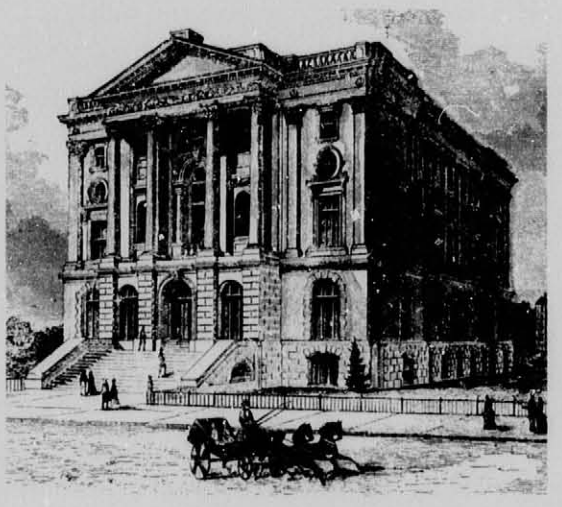
As a great educational institution, we shall fall short of our mission if we fail to inspire in our students a concern for things of the spirit as well as of the mind. By precept and example we must convey to them a respect for moral values, a sense of the duties of citizenship, a feeling for taste and style, and the capacity to recognize and enjoy the first-rate.

* * *

M.I.T. is a product of our age. By its aims, its methods, and its ideals it is keyed to the needs and problems of the contemporary world. Today, more than ever, the measure of our greatness will be determined by our capacity to educate for leadership.

JULIUS A. STRATTON





The Massachusetts Institute of Technology was chartered by the General Court of the Commonwealth of Massachusetts on April 10, 1861. Its first classes, delayed by the Civil War, opened in 1865 in Boston. The move from Boston to M.I.T.'s present campus in Cambridge took place principally in 1916; today the Cambridge campus — a self-contained college community — houses educational facilities and equipment unique in the United States.

M.I.T. is an independent, coeducational, endowed institution; it receives no tax support from the Commonwealth but benefits from a small annual federal grant under the original Morrill Act of 1862, which provides for federal aid to "Land Grant" colleges for agriculture and mechanic arts.

The Corporation

The governing body of the Institute is a body of trustees known as the Corporation. Its members include the Chairman, the President and the Treasurer of the Institute, and more than sixty distinguished leaders of science, engineering, industry, and education. Ex-officio members include the Governor of the Commonwealth, the Chief Justice of the Supreme Judicial Court, and the Commissioner of Education. Four stated meetings of the Corporation are held each year, in October, December, March, and June. Between meetings it functions through its officers and its Executive Committee.

The Corporation appoints Visiting Committees for each department and for certain of the other major activities of the Institute. Members of these Committees, leaders in their respective professions, serve as counselors to the departments and in turn make recommendations to the Corporation concerning departmental activities.

The Faculty

The President presides over the faculty of the Institute, which consists of all professors, associate professors, assistant professors, certain professors emeriti, certain designated instructors and research associates, and a number of administrative officers ex officiis. The faculty annually elects officers — Chairman, Secretary, and Assistant Secretary — and for its government has adopted "Rules and Regulations." These prescribe the faculty's democratic organization and procedures, set forth the faculty's standing committees, and give authority for the appointment of additional special committees. The faculty's rules also provide for a Faculty Council, where questions of major policy receive preliminary discussion in a small group before being submitted for action at meetings of the entire faculty.

In all, there are about 700 members of the faculty. The academic staff of the Institute — including instructors, research associates, and teaching, research, and technical assistants who are not members of the faculty — totals about 1,500.

Administrative Officers

The Institute's chief executive officer is the President. In addition, senior officers include the Chairman of the Corporation, five Vice Presidents, and the Provost.

M.I.T.'s academic departments are grouped into five schools — Architecture and Planning, Engineering, Humanities and Social Science, Industrial Management, and Science, each with a dean as its administrative head. The Dean of Student Affairs is directly concerned with all aspects of student life, and the Dean of the Graduate School is concerned with coordinating educational policies of the graduate program. Officers concerned with the administration of academic affairs meet regularly in the Academic Council. Other administrative officers join them to form the Administrative Council.

The management of research activities which are financed through contracts with government and industry is centered in the Division of Sponsored Research. The Industrial Liaison Office is responsible for fulfilling the contractual obligations of the Institute to a group of leading American companies which make special grants in support of M.I.T.'s program in research and education.

The Students

In all, M.I.T.'s enrollment totals about 6,300 students. Of these, some 3,600 are undergraduates, most of whom enter as first-year students having completed acceptable high or preparatory school programs. However, M.I.T. welcomes a limited number of undergraduate students who have studied one, two, or sometimes three years in other colleges. Of the 2,700 graduate students, roughly one-third hold undergraduate degrees from M.I.T.; others come from colleges and universities throughout the United States and foreign countries. In recent years about 12 per cent of M.I.T.'s graduate and undergraduate students have come from foreign countries. For scholars who hold advanced degrees, M.I.T.'s facilities are available through the School for Advanced Study.

As careers in science, engineering, and architecture have become more available to women, M.I.T.'s enrollment of women students has increased. In a typical year about 155 women are enrolled, 80 of them undergraduates.

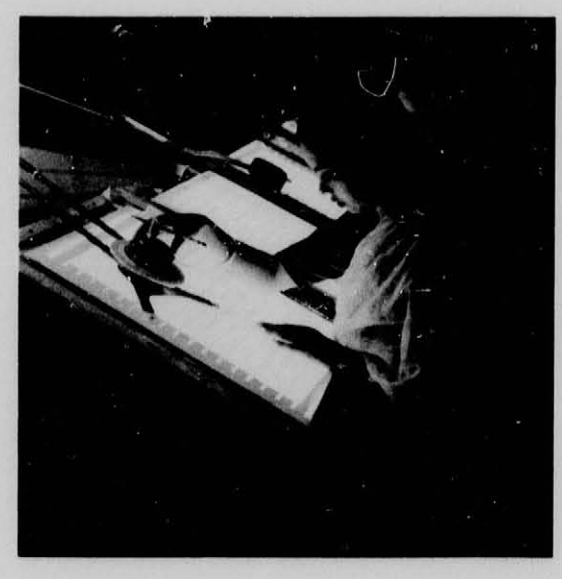
The Institute also accepts a few students who wish to carry on special studies and who are not candidates for degrees; they are known as Special Students.

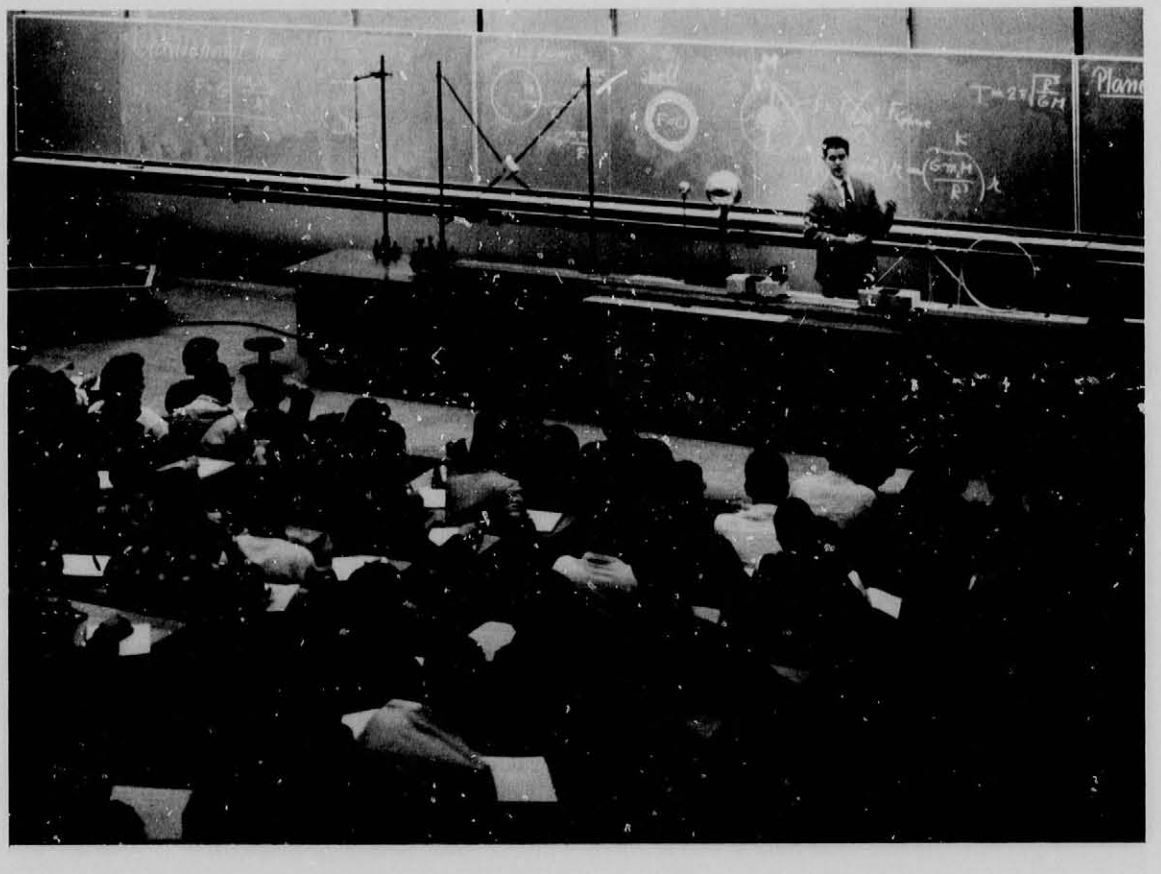


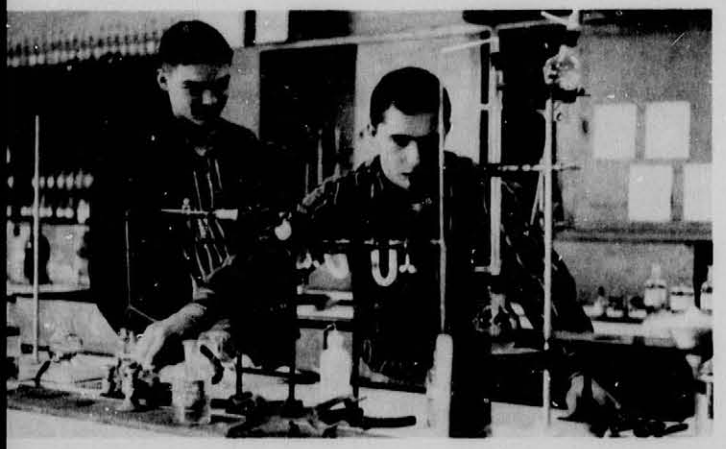


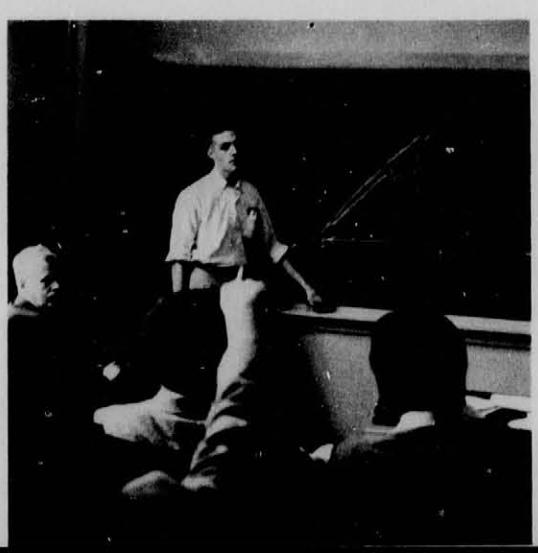












The Academic Program

Within the five Institute schools there are twenty-one academic departments, most of which teach both undergraduate and graduate classes. Each academic department offers one or more degree programs, or Courses of study.

At M.I.T. the word *Course* refers to an organized curriculum leading to a specified degree. The word *subject*, on the other hand, refers to the individual classes. Degrees are awarded on the basis of satisfactory completion of Courses.

Undergraduate Courses at M.I.T. lead to the degrees of Bachelor of Science (S.B.) or Bachelor in Architecture (B.ARCH.). Graduate degrees awarded are Master of Science (S.M.), Master in Architecture (M.ARCH.), Master in City Planning (M.C.P.), Building Engineer (BLDG.E.), Chemical Engineer (CHEM.E.), Civil Engineer (C.E.), Electrical Engineer (E.E.), Engineer in Aeronautics and Astronautics (E.A.A.), Marine Mechanical Engineer (MAR.MECH.E.), Materials Engineer (MAT.E.), Mechanical Engineer (MECH.E.), Metallurgical Engineer (MET.E.), Mineral Engineer (MIN.E.), Naval Architect (NAV.ARCH.), Naval Engineer (NAV.E.), Nuclear Engineer (NUCL.E.), Sanitary Engineer (SAN.E.), Doctor of Philosophy (PH.D.), and Doctor of Science (SC.D.).

The chart on the following pages shows schools, departments, undergraduate and graduate Courses and degrees, and Course numbers.[1] The Cooperative Courses include on-the-job experience at leading industrial plants; they are described more fully in this Section of the Catalogue, under "Other Teaching Facilities," and in the statements of the departments which offer them. Undergraduate Courses require four years of study for the Bachelor of Science degree; five years are required for the Bachelor in Architecture.

Undergraduate Courses and degree requirements are described in Section 2 of this Catalogue; graduate fields of study and degree requirements, in Section 3. The statements of each department in Sections 4, 5, 6, 7, and 8 should be consulted for detailed information about the degrees offered.

Three departments (Air Science, Military Science, and Naval Science) offer undergraduate instruction to all eligible students but are not a part of any one of the five Institute schools. Their programs are described in Section 2.



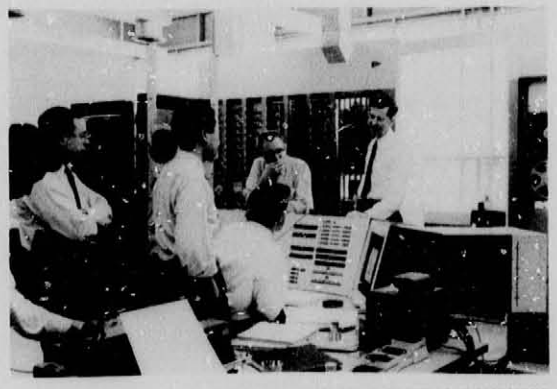
[1] Each Course is designated by a Roman numeral; individual subjects are given Arabic numerals to correspond with the Course numbers. For example, Civil Engineering is Course I; the number 1.07 indicates a subject given in the Course in Civil Engineering.

SCHOOLS, DEPARTMENTS, COURSES, AND DEGREES

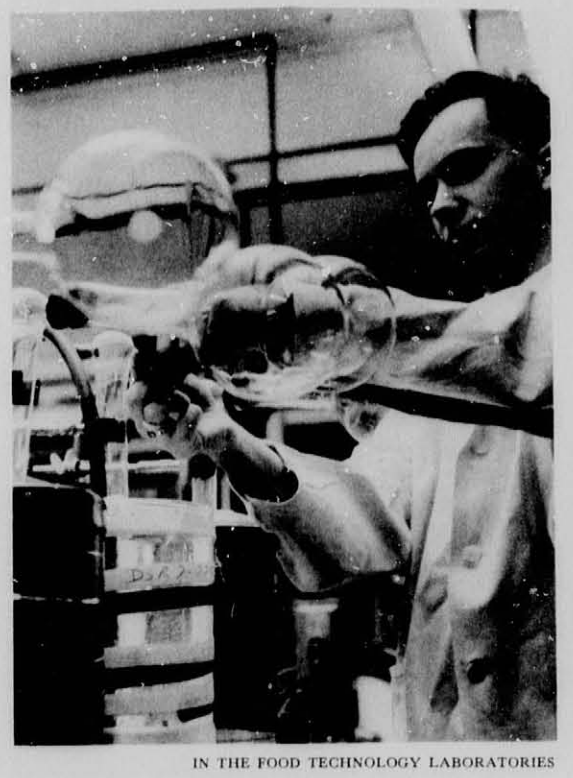
Schools and Departments	*Undergraduate Courses*	*Bachelor's Degrees*	*Course Numbers*	*Graduate Courses*	*Graduate Degrees*
School of Architecture and Planning					
Department of Architecture	ARCHITECTURE[1]	B.ARCH.	IV-A	ARCHITECTURE	M.ARCH.
Department of City and Regional Planning			IV-B	CITY AND REGIONAL PLANNING	M.C.P. PH.D.
School of Engineering					
Department of Aeronautics and Astronautics	AERONAUTICS AND ASTRONAUTICS	S.B.	XVI	AERONAUTICS AND ASTRONAUTICS[2]	S.M. E.A.A. SC.D. PH.D.
	COOPERATIVE COURSE	S.B.	XVI-B		
Department of Chemical Engineering	CHEMICAL ENGINEERING	S.B.	X	CHEMICAL ENGINEERING[2]	S.M. CHEM.E. SC.D. PH.D.
	CHEMICAL ENGINEERING PRACTICE	S.B.	X-B		
			X-A	CHEMICAL ENGINEERING PRACTICE	S.M.
Department of Civil and Sanitary Engineering	CIVIL ENGINEERING	S.B.	I	CIVIL ENGINEERING[2]	S.M. C.E. SC.D. PH.D.
			XI	SANITARY ENGINEERING	S.M. SAN.E. SC.D. PH.D.
			XVII	BUILDING ENGINEERING AND CONSTRUCTION	S.M. BLDG.E.
Department of Electrical Engineering	ELECTRICAL ENGINEERING	S.B.	VI	ELECTRICAL ENGINEERING[2,3]	S.M. E.E. SC.D. PH.D.
	COOPERATIVE COURSE	S.B.	VI-A		S.M.
Department of Mechanical Engineering	MECHANICAL ENGINEERING	S.B.	II	MECHANICAL ENGINEERING[2,3]	S.M. MECH.E. SC.D. PH.D.
	COOPERATIVE COURSE	S.B.	II-B		
				TEXTILE TECHNOLOGY	S.M.
Department of Metallurgy	METALLURGY	S.B.	III-A	METALLURGY[2,3]	S.M. MET.E. MIN.E. SC.D. PH.D.
	MATERIALS SCIENCE	S.B.	III-B		
				CERAMICS	S.M. SC.D. PH.D.

Schools and Departments	*Undergraduate Courses*	*Bachelor's Degrees*	*Course Numbers*	*Graduate Courses*	*Graduate Degrees*
Department of Naval Architecture and Marine Engineering	NAVAL ARCHITECTURE AND MARINE ENGINEERING	S.B.	XIII	NAVAL ARCHITECTURE AND MARINE ENGINEERING	S.M. NAV.ARCH. MAR.MECH.E. SC.D. PH.D.
	SHIPPING AND SHIP-BUILDING MANAGEMENT[3,4]	S.B.	XIII-B		S.M.
			XIII-A	NAVAL CONSTRUCTION AND ENGINEERING[3]	S.M. and NAV.E.
Department of Nuclear Engineering			XXII	NUCLEAR ENGINEERING	S.M. NUCL.E. SC.D. PH.D.
School of Humanities and Social Science					
Department of Economics and Social Science	ECONOMICS, POLITICS, AND ENGINEERING	S.B.	XIV-A		
	ECONOMICS, POLITICS, AND SCIENCE	S.B.	XIV-B		
			XIV	ECONOMICS AND SOCIAL SCIENCE[3]	S.M. PH.D.
Department of Humanities	HUMANITIES AND ENGINEERING	S.B.	XXI-A		
	HUMANITIES AND SCIENCE	S.B.	XXI-B		
Department of Modern Languages			XXIII	MODERN LANGUAGES[3]	PH.D.
School of Industrial Management	INDUSTRIAL MANAGEMENT	S.B.	XV	INDUSTRIAL MANAGEMENT	S.M. PH.D.
School of Science					
Department of Biology	LIFE SCIENCES	S.B.	VII	BIOLOGY[3]	S.M. PH.D. SC.D.
Department of Chemistry	CHEMISTRY	S.B.	V	CHEMISTRY	S.M. PH.D. SC.D.
Department of Geology and Geophysics	GEOLOGY AND GEOPHYSICS[3]	S.B.	XII	GEOLOGY AND GEOPHYSICS[5]	S.M. PH.D. SC.D.
	GEOLOGY AND GEOPHYSICS[3,4]	S.B.	XII-A		S.M.
Department of Mathematics	MATHEMATICS	S.B.	XVIII	MATHEMATICS	S.M. PH.D. SC.D.
Department of Meteorology			XIX	METEOROLOGY[5]	S.M. PH.D. SC.D.
Department of Nutrition, Food Science and Technology			XX	NUTRITION, FOOD SCIENCE AND TECHNOLOGY[3]	S.M. PH.D. SC.D.
			XX-B	BIOCHEMICAL ENGINEERING	S.M. PH.D. SC D.
Department of Physics	PHYSICS	S.B.	VIII	PHYSICS	S.M. PH.D. SC.D.

[1] Five-year undergraduate Course.
[2] The degrees of Materials Engineer (MAT.E.) and Doctor of Science in Materials Engineering are also offered.
[3] See the department's statement for complete information about the specific degrees offered.
[4] Five-year Course leading to Bachelor of Science and Master of Science degrees awarded simultaneously at the end of the graduate year.
[5] The degrees of Master of Science and Doctor of Philosophy in Oceanography are also offered.



THE TX-0 DIGITAL COMPUTER



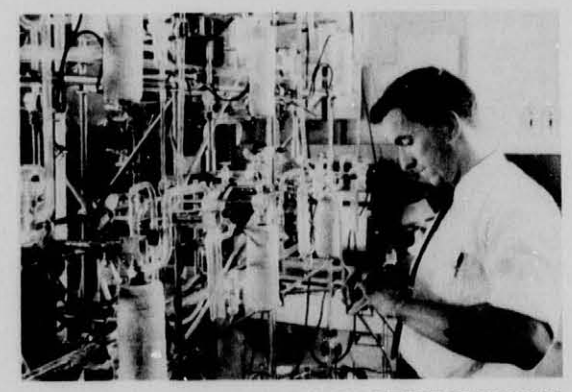
IN THE FOOD TECHNOLOGY LABORATORIES



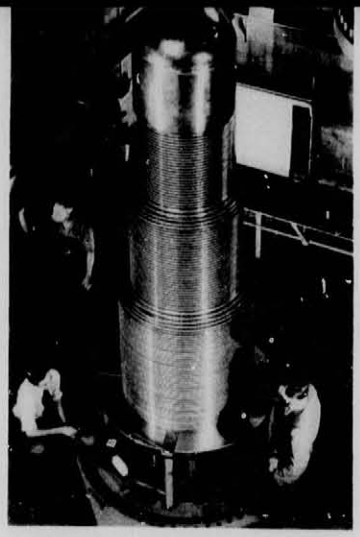
A COUNTER IN THE RADIOACTIVITY CENTER



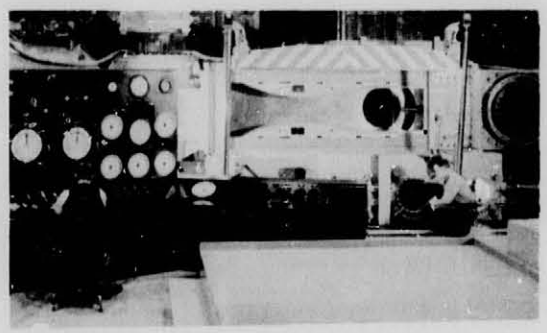
POWDER METALLURGY IN THE METALS PROCESSING LABORATORY



IN THE DEPARTMENT OF GEOLOGY AND GEOPHYSICS



THE ROCKEFELLER VAN DE GRAAFF GENERATOR



THE SUPERSONIC WIND TUNNEL



THE SHIP MODEL TOWING TANK

Research Resources

Research is a major part of M.I.T.'s program. While advancing knowledge of science and engineering, basic research makes special contributions to the Institute's educational program by providing experience at the frontiers of human knowledge for both students and faculty. The Institute receives generous grants from both industry and government in support of extensive research activities in which faculty and students may participate, and it devotes substantial resources of its own to such undertakings. Graduate students share fully in these programs, and undergraduate students often participate. Research is an essential partner with classroom and laboratory education.

The Institute has research facilities unusual — and in some cases unique — among educational institutions. There are more than seventy special laboratories on the campus in Cambridge. For the most part these facilities are described elsewhere in this book by the departments which operate them. Outstanding are the nuclear reactor and Nuclear Engineering Laboratory (Department of Nuclear Engineering); the supersonic wind tunnels and Instrumentation Laboratory (Department of Aeronautics and Astronautics); Electronic Systems Laboratory (Department of Electrical Engineering); and IBM computer in the Computation Center. Round Hill, the ocean-front estate of the late Colonel E. H. R. Green in South Dartmouth, Massachusetts, is used for a number of Institute research activities.

In addition to laboratories and facilities organized within departments, there are several interdepartmental laboratories established so that their activities may freely cross the lines of traditional disciplines. Many of these cooperative research activities are described below.

Cambridge Electron Accelerator

The Cambridge Electron Accelerator, a 6 Bev accelerator made possible by a grant of the Atomic Energy Commission, is being designed and constructed and will be operated jointly by M.I.T. and Harvard on the Harvard University campus. It should be completed and become available for research operations early in 1962.

Center for International Studies

The Center for International Studies was founded in 1951 to conduct social science research on

international affairs. Its establishment reflects the growing interest of M.I.T., whose focus is on the natural sciences and engineering, in the social, political, and economic aspects of technological change. Although the Center has no teaching program of its own, many of its staff are faculty members of the Departments of Economics and Social Science and of Humanities; the Center provides research opportunities which are important to the professional development of these departments. There are also opportunities for graduate students to participate in these research programs.

Current research at the Center includes studies on economic and political development of nations in Asia and Africa, international communications, Soviet scientific research and development, contemporary political developments in the Soviet Union and Eastern Europe, and various aspects of American foreign policy.

Computation Center

The Computation Center is the largest and most versatile data processing facility available today entirely for education and basic research. The Center has the dual role of training students in the use of computer facilities and of assisting research projects. These activities arise both at M.I.T. and at many New England colleges which participate in a cooperative program. An IBM Type 704 Electronic Data Processing Machine was installed at the Center early in 1957 by the International Business Machines Corporation; this has been replaced by a Type 709 machine which will in turn be replaced by a Type 7090 machine early in 1962. IBM contributes to maintenance and operation costs and also makes funds available to students from M.I.T. and many other New England colleges, who work at the Center as research assistants. The computer has been used on problems in economics, artificial intelligence, computer time-sharing, language translation, aerodynamics, operations research, meteorology, plasma research, nuclear theory, and many other fields.

Joint Center for Urban Studies of M.I.T. and Harvard University

The Joint Center was established in 1959, linking M.I.T.'s Center for Urban and Regional Studies (School of Architecture and Planning) with a similar Center at Harvard. The chief aim in forming the Joint Center was to develop a new level of interest in urban and regional studies at both institutions. The Center, with offices at 66 Church Street, Cambridge, encourages basic and applied research on the problems of cities and regions. It also sponsors colloquia, seminars, and professional conferences in which scientists, engineers, social scientists, and experts from the humanities and arts participate.

The activities of the Joint Center provide important research opportunities for faculty members of various departments in both institutions and also for advanced graduate students. Areas of research of special interest include problems of transportation, housing, urban design, technology in relation to urban and regional development, and urban and regional growth in underdeveloped countries.

Laboratory for Nuclear Science

The Laboratory for Nuclear Science was organized to maintain and administer special research facilities in collaboration with the Departments of Physics and Chemistry. Its major equipment now includes a number of high-energy accelerators: a 7-Mev proton cyclotron, a 20-Mev electron linear accelerator, a 350-Mev electron synchrotron, and two Van de Graaff positive ion accelerators capable of producing particles with energies up to 4 Mev and 10 Mev; many other experimental facilities are also available. The Laboratory is engaged entirely in basic research. Among many projects are theoretical studies of the atomic nucleus; studies of the photoproduction of mesons and other high-energy phenomena; studies of the new fundamental particles involving broad experimental endeavors using bubble chambers, fiber scintillation chambers, and complex electronic hodoscopes; studies of cosmic rays, including a program oriented toward the astrophysical aspects of these rays using space satellite vehicles; a program oriented toward the application of high-speed electronic computer techniques to the problems of nuclear data analysis; a broad program of precise nuclear energy level measurements; and programs in medium- and low-energy photo-nuclear and nuclear particle research, radioactivity, and nuclear chemistry. As part of its program, the Laboratory is engaged in experiments in high-energy physics at the Brookhaven National Laboratory. Experiments are also being planned in conjunction with the new 6 Bev Harvard-M.I.T. electron accelerator now under construction.

Lincoln Laboratory

The Lincoln Laboratory, located in Lexington, Massachusetts, was established in 1951 at the

joint request of the U. S. Army, Navy, and Air Force. As a federally supported research center, the Laboratory pursues research and development in advanced electronics with particular attention to national defense and space objectives.

The Laboratory effort includes two component parts: first, a General Research Program in the fields of solid state, information processing, communications, radar, radio physics, systems research, and space surveillance techniques; and second, a group of Specific Projects which are more directly related to defense and space objectives.

Lincoln sponsors a Staff Associate Program, combining full-time graduate study at M.I.T. during the academic year with professional work at the Laboratory during the summer. A number of Staff Associate positions are available to students who can qualify for both employment at the Laboratory and admission to the M.I.T. Graduate School.

National Magnet Laboratory

The world's most powerful magnets, capable of producing continuous magnetic fields of 250,000 gauss, will be part of a new research laboratory now being built at M.I.T. under a contract with the Air Force. The National Magnet Laboratory will be a center for basic research in the fields of solid state, low temperature, and plasma physics. Its facilities will be available to groups from academic, government, and industrial research institutions in the United States and to visiting scientists from other nations. The Laboratory is expected to be in full operation by 1963.

Operations Research Center

For faculty members and graduate students working in the field of operations research, the Operations Research Center provides a focus for interdisciplinary research effort; for arrangements with industry and government offering opportunities to experiment with actual operations; for support of basic research; and for world-wide contacts with other educators in the field. The Center also brings guest lecturers from abroad, sponsors weekly seminars, and provides working facilities for faculty and graduate students, including a large reference collection of articles and reports. Current research includes the fields of transportation, inventory and storage operations, queuing, decision and control processes, linear programming, and machine simulation of operations. In cooperation with the several departments, special programs for the master's and doctoral degrees are coordinated by the Committee on Operations Research. Persons interested in pursuing graduate work in operations research should address inquiries regarding these programs to the Operations Research Center.

Research Laboratory of Electronics

The scope of the research program of this Laboratory is indicated by the fact that the research staff includes faculty and students from nine academic departments. Many diverse interests have been drawn together to form a Center for Communication Sciences, which is concerned with the processing and transmission of information in man and machines. Research fields include communication theory, biophysics, neurophysiology, linguistics, psychology, information processing and transmission, circuit theory, and process analysis and synthesis. Another broad area deals with the interaction of electromagnetic fields with solids, liquids and gases as applied to plasma dynamics, microwave electronics, microwave spectroscopy, maser physics, radio physics and radio astronomy, x-ray spectroscopy, molecular beam research, and nuclear resonance.

Spectroscopy Laboratory

The Spectroscopy Laboratory has pioneered in the ruling of large, high-performance diffraction gratings and in designing, building, and utilizing high-resolution spectrometers. These instruments are used in studies of molecular geometry and in the analysis of complex spectra.

Other Interdepartmental Activities

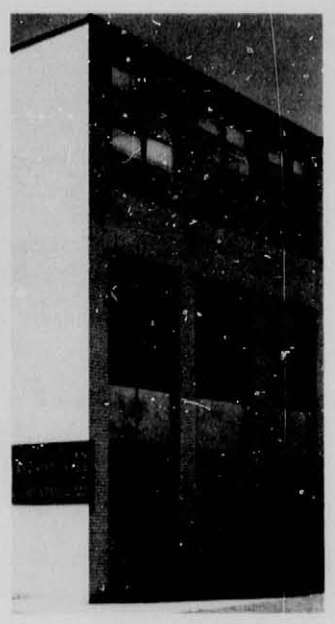
There are, in addition, other interdepartmental groups which indicate the Institute's growing concern with the interrelationships of the scientific and engineering disciplines. A committee on *plastics research* coordinates studies in plastics involving chemical, architectural, and civil and mechanical engineering aspects of plastics. An interdepartmental steering committee is responsible for research in *solar energy utilization.*

The Institute is one of nine universities operating the Brookhaven National Laboratory at Upton, Long Island, New York; its facilities are available to faculty and qualified students in all M.I.T. departments.



THE COMPTON LABORATORIES FOR ELECTRONICS AND NUCLEAR SCIENCE

THE SLOAN LABORATORIES FOR AIRCRAFT AND AUTOMOTIVE ENGINES





THE DORRANCE LABORATORY FOR BIOLOGY AND FOOD TECHNOLOGY

THE CHARLES HAYDEN MEMORIAL LIBRARY



THE GUGGENHEIM AERONAUTICAL LABORATORY



THE ROTCH LIBRARY



THE STEIN CLUB MAP ROOM



THE HAYDEN READING ROOMS



The Campus

M.I.T.'s 115-acre campus extends for more than a mile along the Cambridge side of the Charles River Basin, facing the skyline of Boston. Nearly all the academic activities are brought together in a group of connected educational buildings which are designed to permit maximum flexibility and easy communication among the departments and schools. The extensive athletic plant and playing fields are on the campus, fully accessible. So are the recreational buildings, dormitories, and dining halls.

This convenient arrangement is an expression of the unity that pervades the Institute — unity among the sciences and humanities, among faculty, students, and administration, among the intellectual, social, and recreational aspects of living.

THE LIBRARIES

With resources in excess of 700,000 volumes, the M.I.T. Libraries are designed to facilitate all the Institute programs of study and research. Nearly 7,000 current journals and serials and 1,400 government document series, together with extensive back files, provide comprehensive holdings in all major fields. These are enriched by numerous special collections.

The library system, with headquarters in the Charles Hayden Memorial Library building, includes a General Library and five divisional libraries: The Arthur Rotch Memorial Library of Architecture and Planning; the Dewey Library (economics, industrial management, and industrial relations); the Engineering Library (with a separate Aeronautics branch); the Humanities Library (with a branch Music Library); and the Science Library.

All the services offered by a fine research library are available: reference and information, interlibrary loans, and microfilm or microprint reproductions of works here or in other libraries.

Of special interest in the Hayden building are the Boston Stein Club Map Room, with its unique six-foot revolving relief globe, and the Music Library, whose five-channel audio system was electronically and acoustically designed especially for the main listening room.

The libraries serve primarily Institute students, faculty, staff members, and their families. Visiting scholars and others wishing to use the facilities may apply to the Director of Libraries for a library privilege card.

THE MUSIC LIBRARY





THE ENGINEERING LIBRARY





MUSEUMS

Many departments have their own exhibits, along the corridors adjacent to their laboratories and offices. In addition, the Francis Russell Hart Nautical Museum, containing a magnificent collection of ship models and the Allan Forbes and Arthur H. Clark print collections, has ample quarters of its own. The collections of ceramics and of minerals, though not fully displayed in public, are also distinguished.

In addition to the permanent displays, the Institute provides monthly exhibitions in the New Gallery in the Hayden Library. These presentations, often the only showings of their kind in the Boston area, range from handcraft to machine craft, from primitive through contemporary art.

RECREATION

Athletic and social facilities are an integral part of the campus. M.I.T. seeks in every way to provide its students with a rich and well-rounded college experience, so that as they develop professional competence they also gain experience and insight in many different activities and relationships.

Walker Memorial, built in memory of President Francis Amasa Walker, is the center of student social life. Nearby are the Alumni Swimming Pool and squash courts.

Playing fields for soccer, lacrosse, baseball, softball, football, track, and tennis are on the West Campus. Here, too, are the John Rockwell Athletic Cage, which has a large area for wintertime recreational and varsity athletics, including a portable basketball floor and stands; the Briggs Field House, with lockers and showers to serve the nearby playing fields and Rockwell Cage; and an outdoor artificial-ice rink, used from November through March.

The David Flett du Pont Athletic Center, recently completed on the West Campus, provides new facilities for squash, wrestling, fencing, and gymnastics. This new building is designed to tie together Briggs Field House, Rockwell Cage, and all of the locker facilities available both to men and women. The athletic offices are on the second floor of the du Pont Building.

The boathouse on the Charles River is supplied with eight-oar shells, and there are excellent facilities for dinghy sailing at the nearby Sailing Pavilion.

AUDITORIUM AND CHAPEL

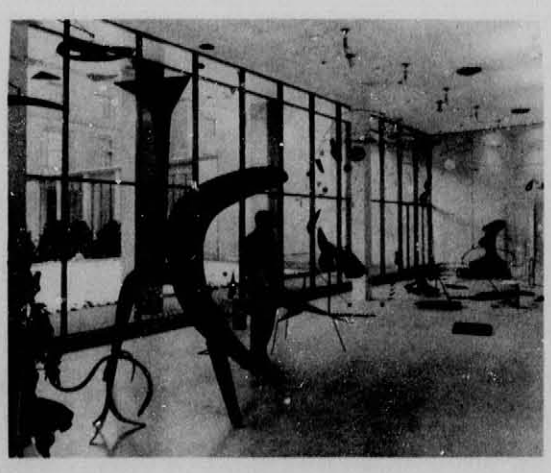
M.I.T.'s contemporary point of view is nowhere better reflected than in the Kresge Auditorium and its neighboring chapel. The auditorium contains a large hall seating 1,200, an experimental theater for 200, and rehearsal rooms for musical and dramatic performances. It thus provides equipment and environment for the finest public performances of music and drama, as well as for lectures and more informal events.

The M.I.T. Chapel, widely recognized for its unusual and effective design, is the center of many religious activities. It is open to, and used by, all religious groups for daily, weekly, or monthly services.

ENDICOTT HOUSE

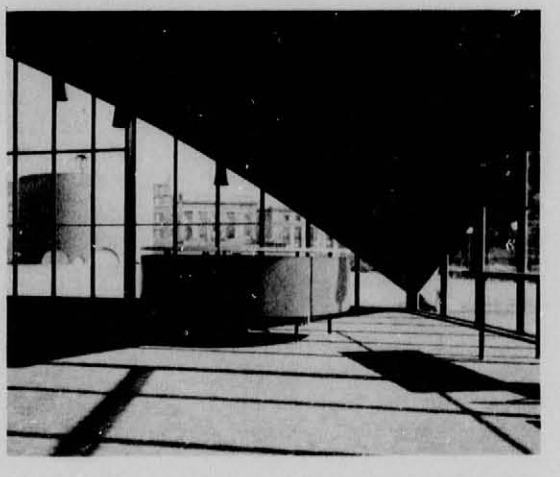
Endicott House, a former private estate located in suburban Dedham, is M.I.T.'s center for off-campus educational and administrative conferences. It has meeting and dining rooms, overnight accommodations for about thirty-five guests, and spacious grounds.

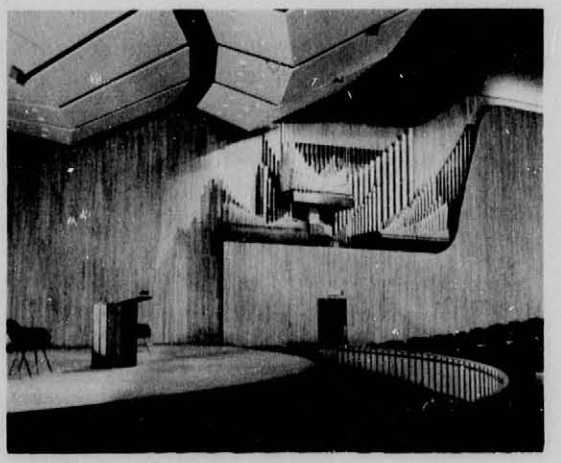
THE HAYDEN LIBRARY GALLERY



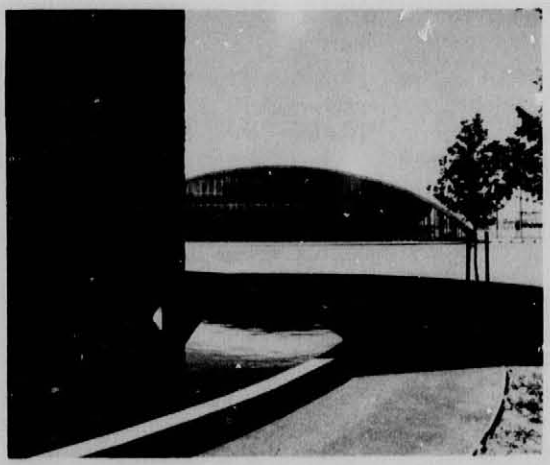
ENDICOTT HOUSE







KRESGE AUDITORIUM



Other Teaching Facilities

The Institute's philosophy of "learning by doing" sometimes carries its teaching program beyond the Cambridge campus. Three departments (Aeronautics and Astronautics, Electrical Engineering, and Mechanical Engineering) have Cooperative Courses of study: Courses combining academic work at M.I.T. with on-the-job practice in industry. Students in these Courses work at a number of industrial plants throughout the country. The Department of Geology and Geophysics shares in the operation of the Nova Scotia Centre for the Geological Sciences, near Antigonish, Nova Scotia.

The unusual experience of solving real engineering problems in the environment of a complex chemical industrial enterprise is open to chemical engineering students at the Massachusetts Institute of Technology through the School of Chemical Engineering Practice. The School operates stations for undergraduates and graduate students at the Bound Brook, New Jersey, plant of the American Cyanamid Company and at the nearby Bayway Refinery of the Humble Oil Company. For an entire semester, first at one station and then at the other, students in the School work and study in these industrial plants under the direction of resident M.I.T. faculty.

The Engineering Practice School at Oak Ridge, Tennessee, is open to qualified graduate students in all M.I.T. departments. Under the direction of members of the faculty resident in Oak Ridge, students study in the Gaseous Diffusion Plant and in the Oak Ridge National Laboratory, both operated for the Atomic Energy Commission by the Union Carbide Nuclear Company. The program emphasizes the application of engineering principles to development, research, or production problems encountered in the rapidly growing atomic energy field.

For both Practice Schools, there are two terms each year — from September through January and from February to early June — each of which carries academic credit for 48 units. The Schools are administered by the Department of Chemical Engineering, and inquiries should be addressed to the Department Headquarters at M.I.T.

Student Housing

In order that students may share fully in the experience of life in an active academic community, M.I.T. encourages all students to live in the Institute Houses or fraternities. As far as accommodations allow, such residence is required for all freshmen unless other special arrangements are approved by the Dean of Residence. Upperclassmen are free to make whatever living arrangements they choose.

In a typical year, nearly half of the undergraduate student body lives in Institute Houses on the campus. Another 30 per cent live in fraternities. About 20 per cent of M.I.T.'s graduate students live in the Graduate House.

DORMITORIES

The Houses for Undergraduate Men

There are comfortable facilities for undergraduate men in twelve Houses on the East Campus and in three Houses west of Massachusetts Avenue. These Houses have been carefully planned for effective community living. There are lounges, recreation rooms, and laundry and hobby facilities; rooms are completely furnished, except for blankets and linen. Many of the Houses front on Memorial Drive, and many rooms overlook the Charles River Basin and Boston skyline. Cafeteria service in Walker Memorial, the undergraduate student center, provides meals for East Campus and Senior House residents. Baker House has its own dining room, as has Burton House.

Members of the faculty are in residence in Burton House, Baker House, the Munroe unit of the East Campus Houses, and the Crafts unit of the Senior House. They collaborate with students in social and intellectual activities and are available for counsel and guidance when needed.

The dormitory system of the Institute is maintained to provide appropriate housing for its student body in an atmosphere conducive to suitable study and living habits. Determination and maintenance of living conditions within the dormitories is the responsibility of the Dean of Residence. Student government has traditionally cooperated with the administration of the Institute in helping to determine and to enforce policies governing dormitory life. It is expected that all students will comply with those rules and regulations currently in effect. The Institute reserves the right to terminate the privilege of dormitory residence for any student found violating either dormitory regulations or acceptable standards of community behavior.

The House Committee in each House, as a part of student self-government, organizes and supervises all athletic and social activities in the dormitories and cooperates with recognized undergraduate activities at the Institute. Financial support for these activities comes from a House tax included with rental.

Residences for Women Students

The M.I.T. Women's Dormitory, at 120 Bay State Road in Boston, about twenty minutes' walk from the Institute, is an attractively furnished house for seventeen girls — one upperclass woman and sixteen first-year women. Residence here is required for first-year women students, except for those who may live in their family homes.

The dormitory provides a home-like atmosphere, and a House Mother is in residence. Breakfast and dinner are served during the academic year by the residents of the House, in accordance with a schedule planned in advance. The girls also have the privilege of preparing their lunches with food provided by the House.

Bexley Hall, at 52 Massachusetts Avenue in Cambridge, is an apartment dormitory for upperclass women and a few women graduate students, totaling thirty-three. The apartments, fully furnished and equipped except for blankets, linen, and draperies, are each arranged to accommodate two or three residents. A member of the faculty and his family are in residence in the Hall, and a number of Institute families have apartments in other sections of the building.

The Graduate House

The Graduate House, with a capacity of 452 residents, is reserved exclusively for men graduate students. It is located at Memorial Drive and Massachusetts Avenue, Cambridge, across from the main educational buildings. The House was established in the belief that "the most natural training comes from free social intercourse between men of different interests but of equivalent intellectual outlook."

In keeping with this belief, the House provides facilities especially designed for congenial living: there are lounges, a library, cafeteria-style dining room, handball court, snack bar (the Buttery), and darkroom. Rooms are fully furnished, except for blankets and linen.

A member of the faculty who is familiar with

the aims and problems of graduate students is Master of the House. A student House Executive Committee, acting with the advice and assistance of the Master, plans and operates the activities program.

The Graduate House is a center for graduate student activities — Graduate House dinners, teas, and twice-weekly informal gatherings in the Buttery. The House organizes teams in touch-football, basketball, bowling, softball, and rugby, and is represented by them in the Institute's intramural program.

General Information

Appendix B of this Catalogue gives information about room assignments, costs, and payment procedures for all of the Houses discussed above and also describes the operating regulations in effect. Details about the dining services and rates are also given in Appendix B. Complete information about living in the Institute Houses and detailed instructions for application are available in a special publication on "Residence at M.I.T.," copies of which may be obtained from the Dean of Residence.

Mail for residents should be addressed to the House concerned: (Alumni Houses, 3 Ames Street; Senior House, 4 Ames Street; Burton House, 420 Memorial Drive; or Baker House, 362 Memorial Drive; or the Graduate House), Massachusetts Institute of Technology, Cambridge 39, Massachusetts. Local and long distance calls to resident men students may be made by calling UNiversity 4-6900 (Cambridge, Massachusetts) and asking for the House concerned.

OTHER HOUSING FACILITIES

Fraternities

Recognized fraternities at the Massachusetts Institute of Technology include twenty-eight chapters situated on private property in Cambridge, Boston, and Brookline. Fraternities participate in M.I.T. student government through the Interfraternity Conference. Each house has one or more members of the Institute faculty or alumni as advisers. Each has its own dining room and provides experience in community planning and living similar to that achieved in the Institute Houses. Further information may be obtained from the Interfraternity Conference, Walker Memorial, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

The M.I.T. Student House

The M.I.T. Student House, organized by a group of alumni, is a cooperative-living house for undergraduate men. In the interest of economical living, students operate the house themselves and do much of their own work. For information about membership, write to the President of the Student House, 111 Bay State Road, Boston 15.

Residences for Married Students

Married students should refer to the Housing Bureau in the Office of the Dean of Residence for local real estate listings.

BURTON HOUSE



EAST CAMPUS



BAKER HOUSE





SYMPHONY ORCHESTRA



BRASS CHOIR



CHORAL SOCIETY



DRAMASHOP



OUTING CLUB



TECH SHOW



Campus Activities

M.I.T. is a community with wide extracurricular interests and liberal opportunities to enjoy them. There are excellent professional programs: most departments sponsor seminar series, many of which attract foreign visitors as well as leading American scientists and engineers. These are supplemented by open lectures on a great variety of current topics.

Lectures, music, drama, art, athletics, and hobbies all make for a many-sided and busy campus. Opportunities are multiplied off-campus. Greater Boston has as wide a range of cultural activity as can be found anywhere in the United States, outside of New York City, and it contributes much to the experiences which await M.I.T. students.

Athletics

The purpose of athletics at the Institute is to encourage all students to participate in some form of physical recreation. The athletic staff is interested in developing life-long recreational interests for each student — not in perfecting the abilities of just a few.

The wide diversity of the intercollegiate program last year provided 1,100 M.I.T. students with competition in eighteen sports, while others joined intramural teams. These figures do not include sailing, by far the most popular recreational activity. More than 1,300 members of the Nautical Association sail for recreation; intercollegiate dinghy racing originated at M.I.T. in 1936, and about seventy colleges from coast to coast have followed that lead.

M.I.T. has varsity and freshman intercollegiate teams in track and field, cross-country running, crew, baseball, skiing, hockey, basketball, fencing, golf, lacrosse, rifle, swimming, tennis, soccer, squash, pistol, sailing, and wrestling. Intramural league competitions are held in touch football, basketball, softball, volleyball, swimming, track, tennis, table tennis, sailing, badminton, hockey, golf, and bowling.

Drama

M.I.T. Dramashop, the student drama group, presents a varied program open to the entire M.I.T. community. It includes each year at least two major productions of full-length plays and four workshop productions of one-act plays directed and acted by students; one of these workshop evenings is devoted to original plays by M.I.T. students. Dramashop also sponsors a Celebrity Series of lectures by prominent theatrical people and productions of plays by well-known theatre groups.

The M.I.T. Community Players, a group of graduate students and staff and their families, present under professional direction a number of plays each year. Tech Show is a musical comedy written and produced by students.

Lecture Series Committee

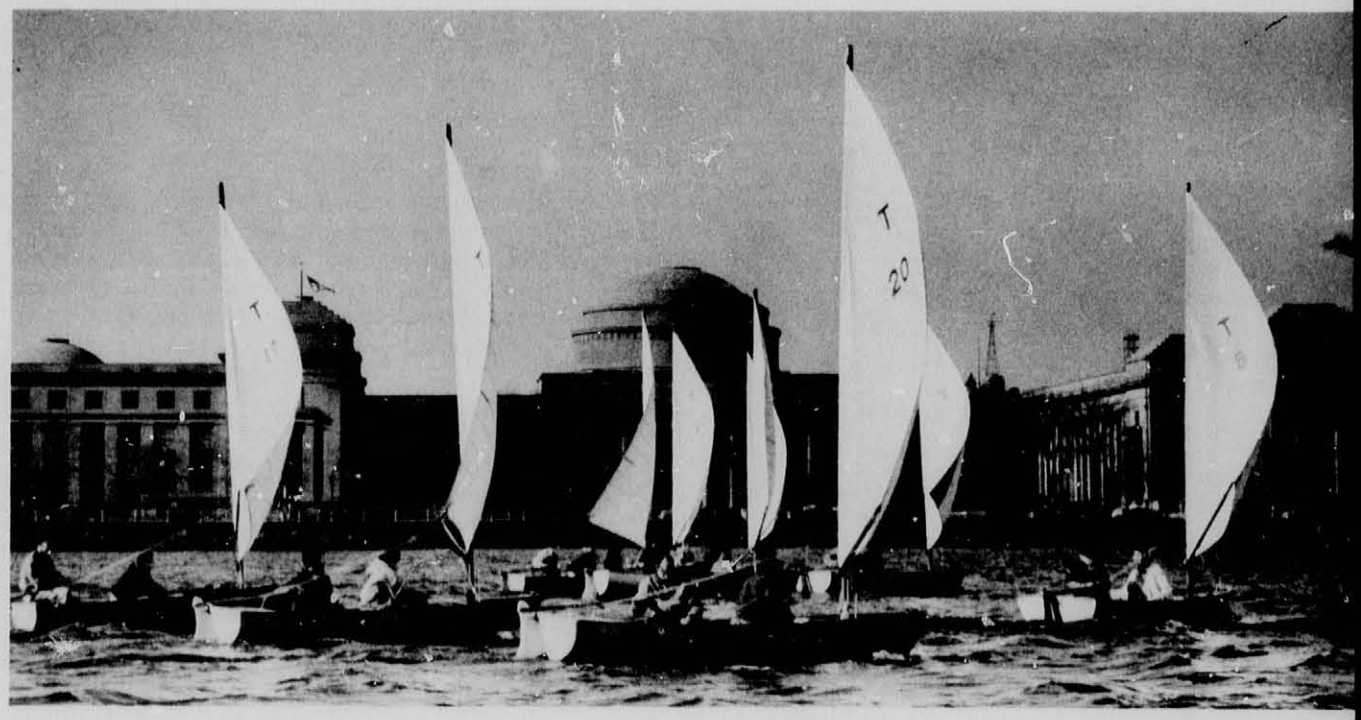
The Lecture Series Committee offers three different types of program for the M.I.T. community: the Entertainment Film Series and the Classic Film Series, which show current popular and older films, respectively; and a strong program of guest lecturers. Recent lecturers have included Barry Goldwater, Strom Thurmond, Wernher Von Braun, Herman Kahn, Arnold Toynbee, Bennett Cerf, Drew Pearson, and Paul Engle.

Society of Arts

The Society of Arts, established by M.I.T.'s charter to provide a contribution to public education, presents each year a series of lectures, usually by members of the Institute staff, which explain various recent advances in science and engineering.

Karl Taylor Compton Lectures

The Karl Taylor Compton Lectures, honoring the memory of M.I.T.'s ninth president, bring to the Institute men who are noted for their broad horizons in science and in philosophy, education, and the humanities. Each Compton Lecturer is in residence during his lecture series and joins faculty and students in seminars and informal discussions. The Lectureship was inaugurated in 1957 by Dr. Niels Bohr; subsequent Lecturers have been Dr. Otto Struve and Dr. André Lwoff.



Arthur D. Little Lectures

The Arthur Dehon Little Memorial Lectureship was established in 1944 "to promote interest in the social implications inherent in the development of science, through lectures by distinguished contributors to the advancement of science and the arts." Lecturers in this annual series have included Sir Edward Appleton, Dr. J. Robert Oppenheimer, Dr. Detlev W. Bronk, Dr. William C. Menninger, Dr. Edwin H. Land, and Dr. George W. Beadle. Lectures are open to the public.

Music

M.I.T. is a musical community. It has a busy season of programs given by many different musical groups, all of which are open to graduate as well as undergraduate students. The Combined Musical Clubs include a Glee Club, Choral Society, Symphony Orchestra, Concert Band, and a Woodwind and Brass Ensemble — all out-of-classroom activities which draw a large following among the musicians in the student body. These organizations give public concerts in Boston and the neighboring communities, frequently in combination with musical groups of other colleges. The Choral Society joins with members of the Boston Symphony Orchestra for two annual major concerts, and in 1958 it sang at the Brussels Fair, in Paris, and in Germany during a four-week summer concert tour; the Glee Club appears with the Boston Pops Orchestra in Symphony Hall; and the Concert Band plays a Sunday afternoon concert at the Hatch Memorial Shell on the Boston Esplanade.

Chamber music groups, symphonic groups, and concert soloists appear at M.I.T. each year as part of the Humanities Series. Other professional musical events are sponsored at the Institute by the Baton Society (the student musical honorary group) and the Choral Society.

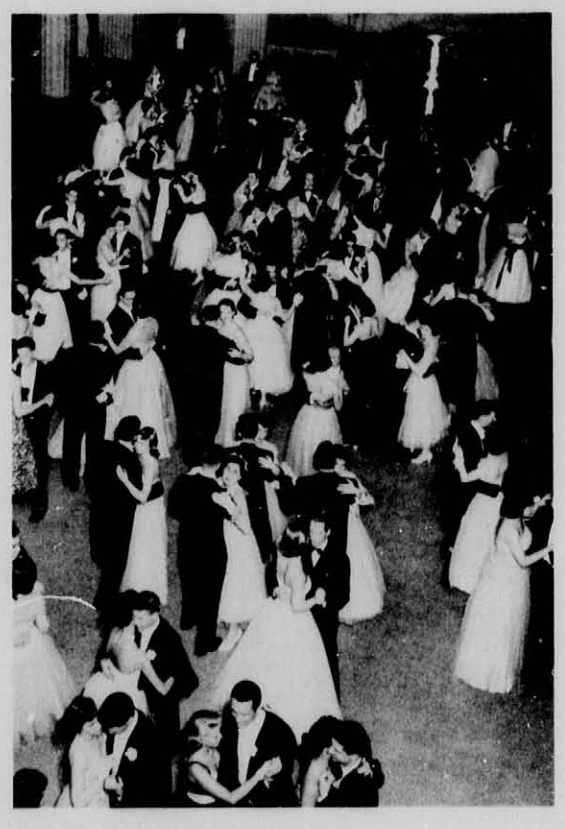
Lowell Institute School

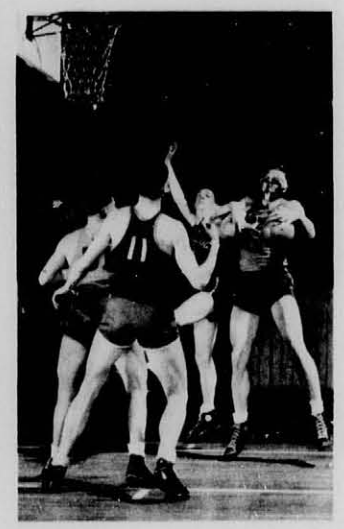
The Trustees of the Lowell Institute established this free evening school in 1903, under the auspices of M.I.T. It offers two regular two-year courses in engineering fundamentals — mechanical and electrical — and on occasion, if the demand justifies, a course in structural or civil engineering fundamentals. A number of supplementary single subjects are also offered. The program is designed to bring systematic

(*text continues on page 26*)











(*text continued from page 24*)

engineering study within the reach of young people in industry who would otherwise be denied these opportunities. For further information, write to the Director of the Lowell Institute School, Room 5-111, Massachusetts Institute of Technology, Cambridge 39.

Lowell Institute Cooperative Broadcasting Council

The Institute has joined other Boston educational and cultural organizations in the Lowell Institute Cooperative Broadcasting Council. Boston's two noncommercial educational stations, WGBH-FM (89.7 mc.) and WGBH-TV (Channel 2), are operated with the advice and cooperation of the Council. The television station was erected by funds donated in honor of Edward A. and Lincoln Filene and by the Fund for Adult Education. The stations are owned by the WGBH Educational Foundation and are operated with funds contributed by the members of the Council and by Friends of WGBH.

M.I.T. participation in this programming is centered in the Office of Public Relations.

Religious Organizations

The long-established programs of the several student religious organizations on the campus have recently been greatly strengthened. Ministers from local churches, representing the major faiths, devote all or a large part of their time to counseling with individual students and advising the student religious organizations. The offices of the Religious Counselors are located at 317 Memorial Drive, near the chapel.

Students take an active part in the religious activities of many of the neighboring churches in Boston and Cambridge. In the last few years the new chapel has made it possible for the religious groups to center more of their activity, especially their services of worship, on the campus.

In accordance with the chapel's interdenominational status, the Institute has not appointed an Institute Chaplain or Dean of the Chapel. M.I.T. considers that one of its responsibilities is to maintain an atmosphere of religious freedom for the individual and, within this environment, to provide adequate opportunity for the development of spiritual maturity and the exercise of spiritual interests.

The Technology Community Association

With the help of a permanent staff, T.C.A. conducts a diversified program of service to the M.I.T. community. Work with Boston boys' clubs, a handbook for new arrivals on the campus, Tech House, and annual blood donor and clothing drives are a few of the activities sponsored by the student members. Tech House, a beachfront cottage at Round Hill, is available to students and faculty; the beach at Round Hill is open to all members of the M.I.T. community.

Student Government

Many of the activities described above — and many more in which M.I.T. students are active — are the responsibility of M.I.T. students through their elected student government. The M.I.T. Undergraduate Association controls a budget of about $47,000, provided by the Institute in support of student activities, and there is a similar organization for graduate student government.

Student Publications

Student publications at M.I.T. include *The Tech*, semi-weekly newspaper; *Technique*, yearbook; *Tech Engineering News*, monthly magazine of engineering students; *Tangent*, a literary review; and *Voo Doo*, humor magazine. There are less formal outlets for journalism talents in the newspapers of the Institute Houses and in departmental newsletters of many kinds. The Graduate Student Council sponsors publication of *A Guide to Graduate Life*.

Other Student Activities

There are more than sixty student activities and clubs at M.I.T., many of them open to both undergraduate and graduate students. Among the most active are the Outing Club, the Model Railroad Club (with its own railroad, the Tech Nickel Plate, on the campus), the Hobby Shop (complete facilities for woodworking, printing, photography, and other activities), the Debating Society, and the Radio Society.

The various professional societies invite outside lecturers to discuss topics of professional interest and provide a forum for the presentation of scientific papers by students. There are also honorary professional societies and social and service groups.

For foreign students, there are organizations where students of like nationalities may meet periodically to participate in cultural and social activities. Service groups, such as Alpha Phi Omega, the national Scouting fraternity, undertake a number of important projects in the Cambridge community each year.

The Technology Dames

The wives of M.I.T. students — both undergraduate and graduate — and of members of the junior staff form the Technology Dames. A social and service organization, the group numbers over four hundred and sponsors twice-monthly program meetings; weekly bridge, swimming, and cultural group meetings; and dances, neighborhood Newcomer Teas, and a "Graduation" dinner. Membership is $2.00 and includes a subscription to the Dames' monthly newsletter.

The Technology Matrons

Wives of the faculty and senior staff, as well as women members of the faculty and senior staff, comprise the Technology Matrons. The Matrons hold six general meetings and a number of smaller group meetings yearly. They also sponsor many service projects for the Institute community.

Medical Services

The Institute maintains a well-equipped Medical Department, centrally located in the Homberg Memorial Infirmary, a wing of M.I.T.'s main buildings. On the first two floors are doctors' offices and special facilities for minor surgery, ophthalmology, otolaryngology, dentistry, x-ray, and laboratory diagnosis. An infirmary with twenty-three beds and an operating room are located on the upper floors. Facilities of the Boston and Cambridge hospitals are used in cases involving major operations or complicated medical procedures, after which students may return to the Infirmary for convalescence.

A Medical Insurance plan has been adopted by the Institute for all students. For a premium of $27.50 per half-year, the insurance company agrees with certain limitations to pay up to $1,500 toward meeting the cost of each illness. In the case of accidental injury, the company will pay the entire cost of medical care up to $1,000 and 80 per cent of any remaining cost up to a total of $8,000, subject to a schedule for surgeons' fees and a limit of $200 for injury to sound, natural teeth. Students who do not wish to be enrolled in this plan must sign a waiver at the time of registration. This insurance is not available to full-time employees of the Institute.

Any student may receive routine medical care in the clinic without charge. If he is referred to one of the special clinics or needs x-ray or laboratory studies, a moderate fee is charged unless he carries Student Medical Insurance. Psychiatric service — covered by Student Medical Insurance through the twentieth visit when prescribed — is charged for after the fifth interview in any one fiscal year.

Infirmary charges are moderate: ward care is $18 per day and private room care is $20 per day. Student Insurance covers the cost of this care. Charges at Boston or Cambridge hospitals which may be used by students on recommendation of the Medical Department are the responsibility of the student; if insured, his hospital room charges up to $21 per day are paid by the insuring agency, together with ancillary charges up to $250.

Prior to matriculation, every entering student, undergraduate or graduate, is required to submit a report of a physical examination performed by his own physician and recorded on an Institute-furnished Medical Form, which is to be mailed by the physician to the Associate Medical Director. Immunizations against smallpox and tetanus are required; immunization against poliomyelitis is recommended but not required. After registering, the student must report to the Medical Department promptly for a medical interview, a dental examination, a tuberculin test and a chest x-ray. Failure to comply with this requirement within six weeks after matriculation will make the student liable to a charge of $10.

Other Services

Among the other important Institute services are:

Alumni Association

The M.I.T. Alumni Association has a complete program for keeping 52,000 graduates and former students informed of M.I.T. affairs. Chief among its publications is the *Technology Review*, a monthly alumni magazine. There are nearly one hundred regional M.I.T. clubs throughout the world, and the Alumni Fund ranks annually in the country's top half-dozen. Other alumni activities include Alumni Day, the Monday following Commencement; class reunions between Commencement and Alumni Day; and day-long Regional Conferences in major cities.

Faculty Club

Membership in the Faculty Club is open to members of the faculty and staff, to many members of the research staff, and to alumni. The Club has comfortable dining and lounge facilities in the Alfred P. Sloan Building at 50 Memorial Drive, Cambridge.

Information Office

This office (Room 7-111) is located in the main lobby at the Massachusetts Avenue entrance. Directions to various M.I.T. destinations, catalogues, directories, Institute maps, and Institute telephone service are available here.

Military and Selective Service Office

M.I.T. undergraduates who may be subject to selective service will find help in their dealings with their draft boards at the Institute's Military and Selective Service Office. A Selective Service College Qualification Test is given each year at M.I.T., and students are advised to take one of these examinations. Upon receipt of a classification questionnaire from the local board, students should report immediately to the above office. Students must be registered for a full-time program during the academic year in order to qualify for deferment. Class 2-S deferments are recommended. The Graduate School Office provides similar assistance to graduate students, described in Section 3 of this Catalogue. The Military Departments arrange for deferment of students who are enrolled in the advanced R.O.T.C. courses.

M.I.T. Women's Association

The M.I.T. Women's Association is an organization of former M.I.T. women students. It maintains a continued interest in women currently studying at the Institute and administers the Lillie C. Smith Fund for special financial aid to women students.

Personal Deposits Office

While students are encouraged to maintain their own checking accounts in commercial banks, the Institute operates a Personal Deposits Office where students may deposit their personal funds in amounts up to $1,000 and draw upon them without charge or interest.

Placement

Without assuming responsibility for finding employment for the graduating class, the Institute's Student Placement Bureau helps students plan for placement and brings them together with prospective employers and their representatives. Students who wish summer work will find similar help here.

An Alumni Placement Bureau helps former students secure positions and aids industry in selecting men for positions requiring engineering or scientific education.

The M.I.T. Press

The M.I.T. Press publishes books of scholarly and technical value. It has a list of a hundred books in print — in science, engineering, the social sciences, industrial management, and the communications sciences. Most of the books are written by M.I.T. faculty and staff members. Books are available through any book store, and catalogues are mailed upon request from Room 14N-325, M.I.T. The Press was founded in 1933. It is a member of the Association of American University Presses.

General Regulations

Academic Year

The academic work of the Institute is given principally in two 15-week periods, as indicated in the academic calendar elsewhere in this book. In addition, a limited number of subjects are given during a 10-week Summer Session in June, July, and August; this Session includes also a number of Special Summer Programs, intensive reviews of special technical fields for those not regularly enrolled at M.I.T. Most classes during the 15-week terms are scheduled between 9 a.m. and 5 p.m. on weekdays and (for first- and second-year students) from 9 a.m. to 1 p.m. on Saturdays. During the Summer Session most classes are held between 8 a.m. and 5 p.m., on weekdays only.

Registration

Each student is required to fill in registration forms and present them to the Registrar on a date before the opening of each term specified in registration instructions.

Faculty Counselors and Registration Officers

Every student is assigned to a member of the faculty who serves as his academic adviser. Each student's program must be approved by this faculty member, and changes may be made only with his approval. First-year students and second-year students who have not yet made a

Course selection have as their advisers faculty members of the Freshman Advisory Council. Other undergraduates enrolled in a department have a Faculty Counselor from that department, and graduate students have Graduate Registration Officers.

The deans, department heads, and all members of the faculty are also available as consultants to students who seek advice relating to their professional careers.

Attendance

The Institute expects regular and prompt attendance in classes and other meetings of the subjects for which a student is registered.

Grade Reports

Grade reports are issued by the Registrar at the end of each term and summer session to all registered students. First-year students also receive informal mid-term reports. Parents of first-year students receive copies of these reports.

At the request of the Bursar, a grade report is not issued to a student whose financial obligations to the Institute are not clear.

Final Examinations

Final examinations are held at the end of each term; the schedule is issued about a month before the examination period. Each student is held responsible for obtaining an examination schedule at the Information Office (Room 7-111), for reporting any conflicts in his examinations before the time limit given on the examination schedule, and for attending the final examinations required in the subjects for which he is registered.

No member of the instructing staff is empowered to grant excuse from a final examination. Absence from any final examination is equivalent to complete failure except as, on presentation of adequate evidence of sickness or other valid reason for the absence, the Dean of Student Affairs may permit a student whose term work has been satisfactory to take the next scheduled examination on the subject.

Condition Examinations

A conditional grade received by a student as a term record entitles the student to a re-examination. Examinations for this purpose are held each year in March for conditions of the first term and in early September for conditions in subjects taken in the second term. Each student is held responsible for obtaining an examination schedule and for filing an application card for condition examinations before the time limit given on the schedule.

Any student who fails to take a condition examination at the scheduled time forfeits the right to the examination. A student who fails to pass a condition or advanced standing examination in a given term is not allowed to register for that subject in the same term.

Examinations for Advanced Standing

Registered undergraduate students of outstanding ability may take examinations for advanced standing during the examination periods in each term, provided that they have never been registered for or attended classes in the subject concerned. Notice of intention must be filed with the Registrar at least three weeks before the examination period. Endorsement by the member of the faculty in charge is required in all subjects which involve laboratory instruction or drawing.

The grade for an advanced standing examination is entered on the student's permanent record; a passing grade entitles him to full credit for the subject as well as to the appropriate placement if the subject is in a sequence.

Withdrawal

Students who withdraw from the Institute must do so through the Office of the Dean of Student Affairs.

Conduct and Discipline

The Institute reserves the right to dismiss at any time a student whom it deems unsatisfactory for any reason. Students are expected to behave with decorum, to obey the regulations of the Institute, and to pay due respect to its officers. Unethical or undesirable conduct which is inconsistent with general good order, wherever it may occur, is held to be sufficient grounds for dismissal.

It is the aim of the faculty so to administer the discipline of the school as to maintain a high standard of integrity and a scrupulous regard for the truth. The attempt of any student to present as his own any work which he has not honestly performed or to pass any examination by improper means is regarded by the faculty as a most serious offense and renders the offender liable to immediate expulsion. The aiding and abetting of a student in any dishonesty is likewise held to be a grave breach of discipline.

Failure to pay financial obligations to the Institute may lead to probation or dismissal.

In case of injury to any building, or to furniture, apparatus, or other property of the Institute, the damage will be charged to the student or students known to be immediately concerned; but if the persons who cause the damage are unknown, the cost of repairing it may be assessed equally upon all the students at the Institute.

Faculty-Student Relations

The faculty does not intend that Faculty Counselors and other advisers should be "guardians" of the student body. M.I.T. expects its students to be responsible individuals, who will seek advice when they need it but who are capable of managing their own affairs. The Office of the Dean of Student Affairs is responsible for all matters pertaining to general student welfare.

The faculty assumes that all students come to the Institute for a serious purpose and that they will conform cheerfully to such regulations as may necessarily be made by the faculty, administration, student government, or the governing bodies of the Institute Houses. It is M.I.T.'s policy to have as few rules and regulations as are consistent with efficient administration and the general welfare.

The Institute's purpose is to provide maximum opportunity — consistent with M.I.T.'s educational aims — for students through their elected student government to regulate their own day-to-day affairs, activities in the Institute Houses and fraternities, and extracurricular activities, including athletics.

Official Notices

It is each student's responsibility to keep informed of all official notices on the Official Bulletin Boards.

Fees, Deposits, and Payments

The regular tuition for full-time undergraduate and graduate students in the first and second terms is $750 per term.[1] Special tuition rates apply to the Summer Session; these are published each year in the Summer Session Catalogue, available about March 25.

Regular students (other than doctoral students and academic staff appointees) and Special Students[2] (including M.I.T. sponsored research staff appointees) who take only a few subjects and apply to the Bursar for a reduction will be charged at the rate of $23 per unit taken either for credit or as listeners. Except for thesis, the minimum tuition is $140 for regular students and for Special Students who are employed by the Institute, and $275 for other special students. The maximum tuition is $750 per term.

The tuition fee for any doctoral student other than academic staff, irrespective of the number of units, is $750 per regular term, except for thesis presentation. If such a student requires only part of a term to complete his thesis, he shall pay initially tuition for the entire term; but after his thesis grade is reported to the Registrar, his tuition will be adjusted on the basis of a charge of $75 per week from the starting date of the term, with a minimum of $150. Tuition fees for members of the academic staff are described below.

The tuition fee for thesis research for the Bachelor's, Master's, or Engineer degree is $23 per unit credit in either regular term, with a minimum of $140 and a maximum of $750. Special Students are not permitted to register for thesis.

The tuition fee for thesis presentation only is $90 for the Bachelor's, Master's, or Engineer degree and $140 for the Doctor's degree. Thesis presentation refers to those necessary academic events beginning with the actual delivery of the completed document. Registration for thesis presentation is appropriate only on Registration Day and then only if the completed document has been delivered. Any work on thesis prior to presentation should be covered by normal thesis registration.

The tuition fee for a student taking cooperative work in electrical engineering (Course VI-A) is $750 per regular term at M.I.T., $500 per summer term at M.I.T., and $250 per term at an industrial plant. Upon recommendation of the Department, a special tuition rate may be set for an unusual case.

Students in the Cooperative Courses in Mechanical Engineering (Course II-B) and Aeronautics and Astronautics (Course XVI-B) will pay the specified tuition fees for the subjects for which they register during the Summer Session they attend. Students in Course II-B will register and pay a $90 tuition fee for the six-month period they are at the plant. Stu-

[1] Tuition will be increased to $850 per term effective with the 1962 Summer Session.

[2] A regular student is one who is enrolled as an applicant for an academic degree; others are Special Students.

dents in Course XVI-B will register and pay a $30 tuition fee for the term they are at the plant.

For the School of Chemical Engineering Practice (Course X-A) or for the Engineering Practice School at Oak Ridge, for the period September through January or February through June, the tuition fee is $750. For a single field station of the School of Chemical Engineering Practice, the fee is $450. For one field station of the Engineering Practice School at Oak Ridge, the fee is $300; for two field stations, the fee is $600.

Tuition Fees for Academic Staff Appointees

An academic staff appointee who is also registered as a graduate student is expected to pay a tuition fee consistent with the amount of time which he can give to his graduate work, the standard of comparison being the tuition fee for a full-time student. The following schedule is in accord with this general principle:

Staff Appointment	*Normal Registration*	*Maximum Registration*	*Tuition per Term*[1,2]
Full-time	24 units	26 units	$375
Half-time	32 units	36 units	$500
Third-time	38 units	43 units	$600

The fee for thesis presentation only is $90 for a Master's or Engineer degree and $140 for a Doctor's degree. Thesis presentation refers to those necessary academic events beginning with the actual delivery of the completed document. Registration for thesis presentation is appropriate only on Registration Day and then only if the completed document has been delivered. Any work on thesis prior to presentation should be covered by normal thesis registration.

When only thesis registration is necessary for completion of a Master's or Engineer degree, the tuition for staff shall not exceed the corresponding tuition for other regular students: namely, $23 per credit unit with a minimum of $140. If a doctoral student requires only part of a term to complete his thesis, he shall pay initially tuition for the entire term; but after his thesis grade is reported to the Registrar, his tuition will be adjusted from the starting date of the term on the basis of a weekly charge of one-tenth of his initial tuition, with a minimum of $150.

Academic staff appointees who are also graduate students may, by approval of the appropriate department and the Division of Sponsored Research, engage in D.S.R. research but without increased compensation. Such research may, by previous approval of a department Committee on Graduate Students, be a part of a thesis for which registration will be required.

Upon recommendation of a department, the Dean of the Graduate School may set a special tuition rate for an unusual case.

No bills are sent. All payments are to be made to W. A. Hokanson, Bursar, Massachusetts Institute of Technology, Cambridge 39, Massachusetts, by the time specified in the registration instructions issued prior to the opening of each term. Many students choose to make their payments on installment or credit plans, described below.

Tuition Refunds

Full-time students withdrawing during the term will be charged $75 per week from the starting date of the term; for others the charge will be proportionately adjusted, using ten weeks as a basis. A student is financially obligated to the Institute for the fees appropriate to the program approved by his Faculty Counselor or Graduate Registration Officer at the first of the term. Any subsequent reduction in fees is based on the date that notice of cancellation of a subject or withdrawal from the Institute is received at the Registrar's Office.

Dormitory Rentals and Meals

All term rentals, both for the Graduate House and all undergraduate Houses, and all fees for

[1] In cases where assigned research is also approved for thesis, a full-time or half-time staff appointee occasionally has the opportunity to progress at a rate faster than that tabulated. In such a case, as determined by the staff appointee's department and approved by the Dean of the Graduate School, the staff appointee (whether full-time or part-time) who has the opportunity to progress on thesis research at the rate of a full-time student shall pay the full tuition fee ($750 per regular term) and shall be permitted to register for a full academic load of 48 units. A staff appointee who can progress on thesis research at the rate of a half-time or a third-time appointee shall pay a tuition fee of $500, or $600, per regular term, and shall be permitted to register for a maximum of 36 units or 43 units, respectively. In intermediate cases, the tuition principle may normally be satisfied by an appropriate combination of thesis research registration and tuition fee for a full-time and part-time appointee in successive terms. The increase in academic load above the range normal for the academic appointment is limited to thesis.

[2] Graduate degree candidates who are academic staff appointees are permitted to register in one scientific language subject (as 23.17, 23.57, or 23.97) per term without having the time included in the total permissible registration, and without extra tuition.

commons meals are to be paid to the Bursar at the beginning of each term. Students may arrange to make periodic payments, as with tuition fees; such arrangements should be made at the Bursar's Office, Room 4-106, before the beginning of the term. *No bills are sent.*

Application Fee

A fee of $10 must accompany all final applications for undergraduate admission from citizens of the United States and Canada. Because of currency restrictions, this fee is waived for foreign applicants.

Other Fees

A charge of $10 is made for each condition or special examination and $10 for the completion of incomplete work. The premium for medical insurance, which is required of all students who do not sign waivers, is $27.50 per half-year.

Late Registration or Payment Fine

A fine of $5 is imposed for late registration or late payment of fees. Registration is not complete until all fees are paid or arranged for.

Deposits for Chemical Supplies and Military Uniforms

A deposit of $50, from which will be deducted the costs of laboratory chemicals and supplies, damage to military uniforms, and shoes and other non-returnable equipment, is required of:

1. All first-year students and students taking MILITARY SCIENCE (MS21 and MS22) or AIR SCIENCE (AS21 and AS22).
2. All undergraduate and graduate students taking subjects requiring supplies from the Office of Chemical Laboratory Supplies.

All deposits must be made at the beginning of the academic year. Refunds are made at the end of the year; if the total cost of chemicals and supplies used exceeds the amount of the deposit, the extra charges must be paid at the end of the year. No refunds are made during the academic year except to students who leave the Institute

Financial Aids

M.I.T. has a broad program of financial assistance for both undergraduate and graduate students. Four types of financial aid are available to undergraduates: scholarships, long-term low-interest loans, and part-time campus work, discussed in Section 2 of this Catalogue; and deferred payment plans, described below. For graduate students there are scholarships, fellowships, loans, and a number of teaching and research appointments, all described in Section 3. Scholarships, fellowships, and loan funds are listed in Appendix A. The two deferred payment plans described below are also available to both undergraduate and graduate students.

DEFERRED PAYMENT PLANS

Budget Payment Plan for Fees

A student or his parents may arrange with the Bursar, by mail or in person, to pay fees in eight installments during the academic year. This arrangement may include all or part of the total charges incurred by the student. No interest or carrying charge is levied for this privilege. Such an arrangement should be made before the beginning of the term and not later than the Wednesday before Registration Day.

An example of a maximum arrangement for the 1961–62 fees is shown at the top of the next column.

Other budget plans may be arranged, providing that all charges incurred during the summer and fall semesters are paid by the end of the fall semester and all spring semester charges are paid by the end of that semester. Plans for spreading charges over a twelve-month period may be arranged. The first payment for the expenses of the year would then be made on July 1 and the last payment on the following June 1.

EXAMPLE OF BUDGET PAYMENT PLAN

Fees		*Payments*	
Tuition	$1,500.00	September 13	$ 300.00
Average dormitory rent	370.00	October 16	300.00
		November 15	300.00
Commons meals	412.50	December 15	300.00
Medical insurance	55.00[1]	January 3	300.00
Laboratory and/or military equipment deposit	50.00	March 1	300.00
		April 2	300.00
		May 1	287.50
	$2,387.50		$2,387.50

[1]Covers a twelve-month period.

In the event of the termination of the student, all fees due will be expected to be paid by special arrangement with the Bursar.

Installment Credit Plan for Tuition

To provide a new source of financial assistance and to help alleviate the burden of educational costs for students and their parents, the Institute has initiated an optional Installment Credit

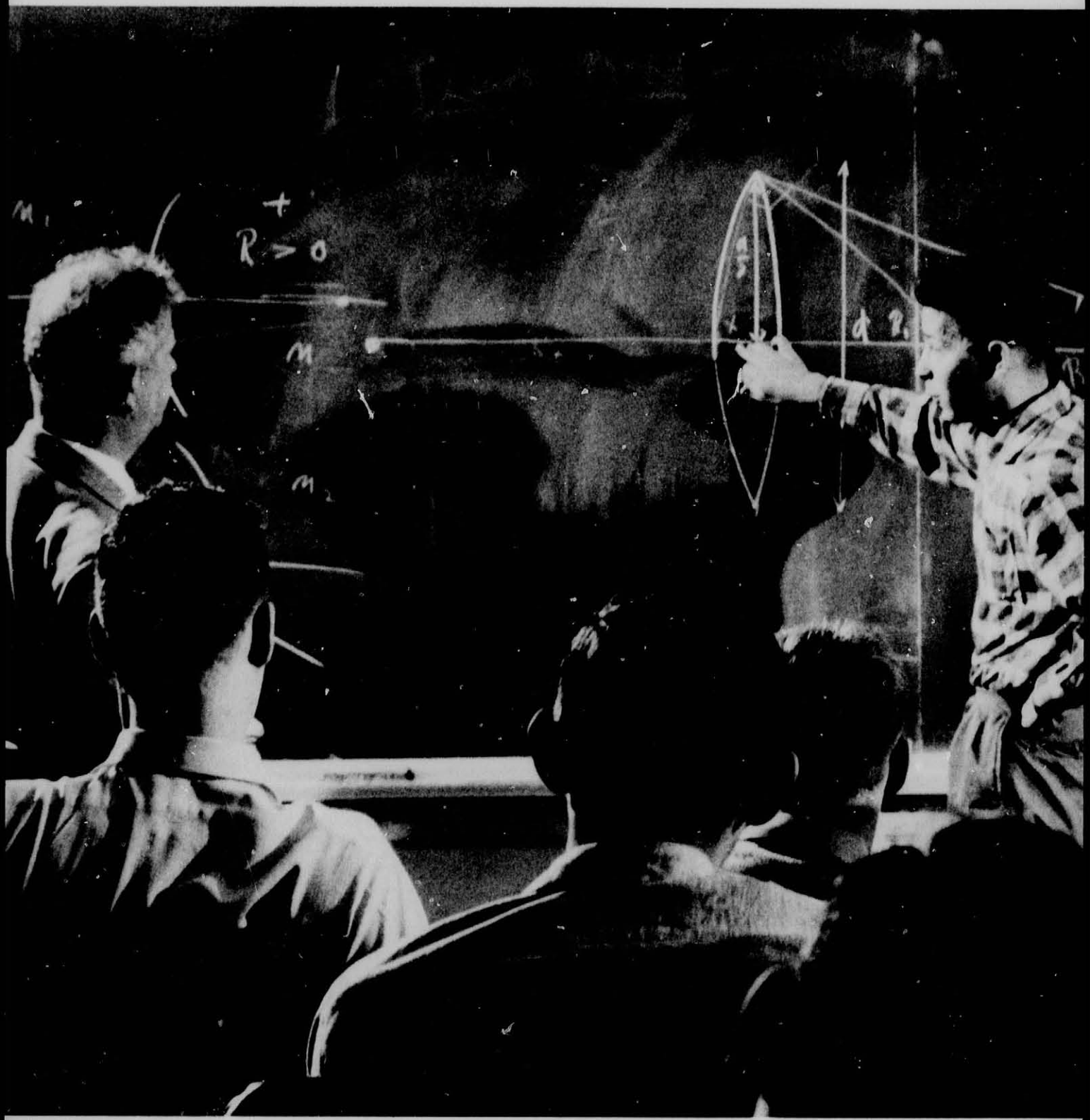
Plan for the payment of part of the M.I.T. tuition fee. Under this plan, any tuition cost in excess of $1,000 may be met by applying to the Director of Student Aid for credit in amounts of up to $700 for an academic year. Thus a student may use the Credit Plan to obtain a maximum four-year credit of $2,800.

The M.I.T. Installment Credit Plan is available to all degree candidates, including entering freshmen, who are citizens of the United States and who are in satisfactory academic standing at the Institute. To keep the interest rate as low as possible, the Institute will underwrite all installment credit and bear all handling and collection costs.

The repayment schedule is liberal. Payments begin six months after the first credit is granted and are continued at six-month intervals so that the total credit will be repaid within ten years of the first year of enrollment (as a freshman) at the Institute. Thus a student will have until six years after his graduation with the bachelor's degree to complete these payments.

Credit extension under the installment plan requires a semi-annual payment of $6.72 for each $100 of credit. This rate of repayment represents an apportioning of interest and principal per $100 of credit for a ten-year period based on an interest charge of 6 per cent on the unpaid balance. All repayments are made to the Bursar at M.I.T., and the balance of the principal may be paid in full at any date.

Application for credit under this plan should be made to the Director of Student Aid no later than one week prior to the opening of the term for which the credit is desired. No Parents' Financial Statement need be submitted, and no collateral is required. However, students who are minors will be asked to have a parent or guardian co-sign their applications. Further information and complete repayment schedules are available from the Office of Student Aid.


R>0











UNDERGRADUATE EDUCATION 2.

The Massachusetts Institute of Technology maintains a tradition of excellence in preparing its students for professional activity. Because standards of admission are high, the educational program is at a level where students may expect to progress rapidly and to move far toward professional achievement in their four years of undergraduate study.

Engineering, science, architecture, management, and humanities and the social sciences are the fields of principal concentration in undergraduate education at M.I.T. The underlying themes are the purposeful applications of science through engineering, the study of science for its own sake, and the impact of engineering and science upon our physical environment and upon our conduct of industry and government. An integrated program of studies in the humanities and social sciences extends through the undergraduate years, giving balance to the whole, developing powers of judgment and taste, and strengthening the student's ability both to meet the basic requirements of his profession and to take his part in the wide responsibilities of public and private life.

Each Course curriculum leading to a Bachelor's degree consists of a program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements), and a grouping of subjects in the areas of professional interest in that particular Course (the Departmental Program). A large part of the educational experience is common to all undergraduates; the General Institute Requirements comprise about half of each curriculum and are essentially the same for all Courses. The Departmental Programs build directly on the basic subjects of mathematics, physics, and chemistry and go on to develop special competence in the field which each student has chosen.

The Institute believes that this pattern is a fitting design for modern education, excellent for those who will follow professions in architecture, engineering, science, economics, or industrial management, and offering, moreover, a sound foundation for careers partly or wholly unrelated to these professions.

The Undergraduate Programs

An undergraduate at M.I.T. may choose his major field of study from among twenty-five Courses. The program for the Bachelor of Science degree requires in each case four years of study; Architecture (Course IV-A) requires five years for the degree of Bachelor in Architecture. To complete work for a Bachelor's degree in any Course, the student must take certain subjects specified by that Course, but he has considerable freedom in planning his academic program. Electives, the substitution of other subjects for certain of those specified in his Course, and, for superior students, the opportunity to take examinations for advanced standing, all allow him to design a program around his own particular interests and abilities.

The first-year program is common for all Courses except Architecture. It provides a broad educational foundation by concentrating on the study of mathematics, physics, chemistry, and humanities. During the second year there is continued common study of mathematics, physics, and humanities alongside the beginning subjects in the Departmental Programs. In the third and fourth years there is increasing diversity among the Courses as the students concentrate on their Departmental Programs.

The curricula for all the Courses are given in Sections 5 through 9 of this Catalogue, where descriptions of the departments in each school are arranged alphabetically by school. The General Institute Requirements are set forth in each school's description of its undergraduate program, and the Departmental Programs are listed by each department.

A complete list of undergraduate and graduate Courses and degrees is given in Section 1. As indicated, the Departments of City and Regional Planning, Meteorology, Modern Languages, Nuclear Engineering, and Nutrition, Food Science and Technology offer graduate degrees only. Information about undergraduate preparation for advanced work in these fields is given by each of these departments. Three departments which do not have Courses do offer subjects: Air Science, Military Science, and Naval Science.

Selection of Course

Many entering students have a well-defined preference for a specific field, while others have interests in several areas and have not yet decided upon a field of concentration. Experience shows that a substantial percentage of those who do enter with a decided preference find other areas to be more to their liking, and therefore every student should be prepared to examine with an open mind all of the various Courses available at the Institute. Students are encouraged to attend departmental orientation programs and to seek out and talk with faculty and others who have experience in fields of potential interest to them. For many students this examination will reinforce existing convictions, while for others it will open up new avenues of interest; in either instance the result will be beneficial.

The faculty recognizes that the most effective educational ally it can have is the absorbing interest of a student in the material he is studying. It believes, therefore, that the primary aim of each student in choosing a Course of study should be to find that area which holds maximum interest for him. Each of the undergraduate Courses combines the study of basic principles with the study of their application in particular situations. From the interest aroused by this combination of principles and applications studied in depth in a particular Course comes the motivation for the continuing learning which leads to professional competence.

A student may enroll in a Course as early as the end of his first year, and he must do so by the end of his second year. This arrangement affords the opportunity for early concentration by a student who has settled on his Course and, at the same time, provides ample time for others to explore their interests, assess their abilities, and choose a Course which satisfies both.

When a student enrolls in a Course, he is assigned a Faculty Counselor from the department in charge of that Course. A second-year student who is not enrolled in a Course is assigned a special Faculty Counselor. During his second year such a student is advised to use his elective time for subjects which are appropriate to the Courses which he is considering. It is important that these subjects be selected with care, since one result of choosing a Course at the end of the second year can be the exchange of elective freedom in the third and fourth years for that used in the second year. Another reason for using care in the selection of these subjects is the fact that, although the elective subjects taken in a normal program during the second year will be accepted as satisfying part

of the Departmental Program in all Courses, an inappropriate choice may delay graduation in some instances because of scheduling difficulties.

Premedical Education

Each year from fifteen to twenty students enter medical school from M.I.T. The majority of premedical students take the Biology Course, but the specific requirements for entrance into medical school can be met in almost any of the Institute's Courses by proper planning. This type of premedical program fully meets the specifications of the Association of American Medical Colleges.

The flexibility and diversity of the programs which are available make it desirable that each student have individual and specialized guidance from a qualified member of the Institute faculty, who serves each year as the official adviser to premedical students.

Science and Mathematics Teaching

Students who are interested in careers in teaching high school science or mathematics may arrange five-year programs combining studies at the Institute and at the Harvard Graduate School of Education. Programs are coordinated by the Department of Humanities, and further information may be obtained from Professor Howard R. Bartlett, Head of the Department.

Program for the Bachelor's and Master's Degrees

Any regular undergraduate student may undertake a program of study leading to the simultaneous award of the Bachelor's and Master's degrees, provided his department recommends him to the Secretary of the Graduate School as a candidate for the Master's degree. He must be enrolled at least one term as a graduate student and complete the requirements for both the Bachelor's and Master's degrees, including a single thesis of not less than 30 units for both degrees, or a Master's thesis of not less than 20 units in addition to satisfying the undergraduate thesis requirement in his department. The requirements for the various cooperative, honors, and other five-year Courses leading to the S.B. and S.M. degrees are specified under the appropriate department statements.

Subject Registration

It is not usually necessary to restrict the number of students admitted to a subject. If an unexpectedly large number applies for an elective subject, however, it may be necessary to limit enrollment for the term to a number commensurate with the available staff and with the subject's educational objectives.

System of Credits

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 term. Each subject is listed with three credit numbers, representing (1) classroom time, (2) laboratory (or drawing) time, and (3) preparation time. The typical undergraduate student load is 45 to 50 units per term. The division of time between lecture (or recitation), laboratory (or drawing), and preparation is shown in the Descriptions of Subjects.

Degree Requirements

To be recommended for the degree of Bachelor of Science or Bachelor in Architecture, a student must have attended the Institute not less than one academic year, which ordinarily must be the year of his graduation. He must have completed satisfactorily a program of study approved in accordance with "Rules and Regulations of the Faculty." Other degree requirements (with the exception of the physical education requirement, described below) are covered in the Course curricula of each department.

Physical Education

The Institute expects each student to gain experience in recreational athletics during his first two years at M.I.T.; by the end of this period he must have compiled at least 8 points of athletic credit. These points may be acquired by participating in a physical education class (2 points) or by membership on one of the 17 intercollegiate freshman or varsity teams (2 points for fall or spring sports, 4 points for winter sports).

Upon entering M.I.T. each student must complete a medical examination, swimming test, and physical fitness test. Those who do not meet certain minimum standards are recommended for swimming or development classes. If the medical examination indicates any disability which might limit physical activities, these athletic requirements are modified accordingly.

Although there are no specific requirements for women students, facilities are provided for the activity of their choice.

The First-Year Program

During the first year, students take a common core of required subjects in mathematics, physics, chemistry, and humanities which are part of the General Institute Requirements. This combination of core subjects provides an appropriate preparation for all the Courses of undergraduate study offered at M.I.T. In addition to these required subjects, which total 78 units, each student takes elective subjects which must total at least 12 units.

There is an exception to this first-year program for students who plan to enter Architecture (Course IV-A). The Architecture curriculum does not include chemistry as a required subject, but it does include graphics and descriptive geometry.

The program for the two terms of the first year is given below.

First Term

		Units
5.01	GENERAL CHEMISTRY[1]	4 2 5
8.01	PHYSICS	4 1 6
18.01	CALCULUS	3 0 6
21.01	INTRODUCTION TO THE HUMANITIES	3 0 5
	Elective subject[1,2]	6
	Total	**45**

Second Term

5.02	GENERAL CHEMISTRY[1]	4 2 5
8.02	PHYSICS	4 1 6
18.02	CALCULUS	3 0 6
21.02	INTRODUCTION TO THE HUMANITIES	3 0 5
	Elective subject[1,2]	6
	Total	**45**

[1] Students who plan to enter Architecture (Course IV-A) are not required to take chemistry; 2.721 GRAPHICAL CONCEPTS (0–4–2) and 2.722 DESCRIPTIVE GEOMETRY (0–4–2) are required; a total of 22 elective units must be carried; GENERAL CHEMISTRY (5.01, 5.02) may be taken as elective.

[2]Students accepted for the A.F.R.O.T.C. or N.R.O.T.C. Programs take as elective subjects either AS11 and AS12 or NS11 and NS12. See the descriptions of these programs later in this Section of the Catalogue.

Some entering students will have taken subjects in secondary school which cover the content of one or more of the required first-year core subjects. The procedures by which credit for this work may be obtained are outlined under "Advanced Placement," later in this Section of the Catalogue. Students who obtain credit for required core subjects will have time available to go on to other subjects of their choosing.

ELECTIVE SUBJECTS

The 12 units of electives (22 units for Architecture) in the first-year program may include Approved First-Year Elective Subjects or upperclass elective subjects, including language subjects, for which the student is qualified. Students planning to elect Air Science, Military Science, or Naval Science subjects should refer to the R.O.T.C. Programs, which are described later in this Section.

Students are urged to use their electives to explore fields of potential interest. Some of the descriptions of departmental curricula include suggestions of electives which these departments consider to be particularly appropriate as background subjects. Further information is available from the students' Freshman Advisers.

Approved First-Year Elective Subjects

The following subjects are approved as first-year electives only and may not be used for upperclass credit. The number of students admitted to any one of these subjects will depend upon the facilities available.

First Term

2.721	GRAPHICAL CONCEPTS (0–4–2)
2.722	DESCRIPTIVE GEOMETRY (0–4–2)
2.723	ELEMENTARY NOMOGRAPHY (2–0–4)
4.011	GRAPHICS LABORATORY I (0–3–2)
6.41	INTRODUCTION TO AUTOMATIC COMPUTATION (2–0–4)
12.001	ASTRONOMY I (3–0–3)
18.00	ELEMENTARY NUMBER THEORY (2–0–4)
20.00	MAN'S FOOD (3–0–3)
21.001	PHILOSOPHY AND SCIENTIFIC METHODOLOGY (2–0–4)
21.002	ENGLISH COMPOSITION (2–0–4)
21.005	PUBLIC SPEAKING (3–0–3)
AS 11	[1]EVOLUTION OF WARFARE (3–1–5)
MS 11	MILITARY SCIENCE (2–1–0)
MS 21	MILITARY SCIENCE (2–1–0)
NS 11	[1]ORIENTATION AND SEA POWER (3–1–5)
SEM 11	[2]UNDERGRADUATE SEMINAR (0–6–0)

Second Term

2.00	INTRODUCTION TO ENGINEERING (2–0–4)
2.721	GRAPHICAL CONCEPTS (0–4–2)
2.722	DESCRIPTIVE GEOMETRY (0–4–2)
2.723	ELEMENTARY NOMOGRAPHY (2–0–4)
3.09	STRUCTURE OF MATERIALS (3–0–3)
4.00	STRUCTURE OF THE CITY (3–0–3)
4.012	GRAPHICS LABORATORY II (0–3–2)
6.41	INTRODUCTION TO AUTOMATIC COMPUTATION (2–0–4)
7.00	PERSPECTIVES IN LIFE SCIENCE (3–0–3)
12.00	EARTH SCIENCE (GEOLOGY, GEOPHYSICS, GEOCHEMISTRY) (2–0–4)
12.001	ASTRONOMY I (3–0–3)
18.08	TOPICS IN DISCRETE MATHEMATICS (2–0–4)
19.003	ELEMENTARY METEOROLOGY I (2–0–4)
21.002	ENGLISH COMPOSITION (2–0–4)
21.005	PUBLIC SPEAKING (3–0–3)
AS 12	[1]FOUNDATIONS OF AIR POWER (3–1–5)

(continued on next page)

(Second Term Elective Subjects continued)

MS 12	MILITARY SCIENCE (2–1–0)
MS 22	MILITARY SCIENCE (2–1–0)
NS 12	[1]ORIENTATION AND SEA POWER (3–1–5)
SEM 12	[2]UNDERGRADUATE SEMINAR (0–6–0)

[1] Open only to students accepted for A.F.R.O.T.C. or N.R.O.T.C. programs (see later description in this Section of the Catalogue).
[2] Separate brochure is available.

The Undergraduate Program in Humanities and Social Sciences

The M.I.T. program in humanities and social sciences has several objectives. It seeks first to develop attitudes and skills basic to a life of effective thought, action, and appreciation as a responsible citizen and broadly educated human being. Secondly, it seeks to provide some understanding of man's experience at key points in his history and of the human problems which must be the concern of every civilized man. Thirdly, it seeks to provide some sense of the intellectual discipline involved in a particular area in the humanities or social sciences, some cutting in depth in a field outside the student's professional specialization. Finally, it seeks to develop skill in accurately and effectively communicating facts and ideas orally and in writing.

Every candidate for a Bachelor's degree must take eight term subjects in the humanities and social sciences; normally these are distributed over the eight terms of his residence, one to each term. All undergraduates may take, if they choose, two additional humanities or social science subjects in place of two professional electives.

In his first two years each student takes a series of four subjects: INTRODUCTION TO THE HUMANITIES (21.01, 21.02) and MODERN WESTERN IDEAS AND VALUES (21.03, 21.04). Through intensive work with original texts he is given training in critical reading, a sampling of the liberal disciplines — notably history, philosophy, and literature — and a foundation for more advanced study in these and related fields. Frequent written exercises, with criticism from his instructors in scheduled conferences, give him an opportunity to improve his writing ability.

(text continued on page 42)



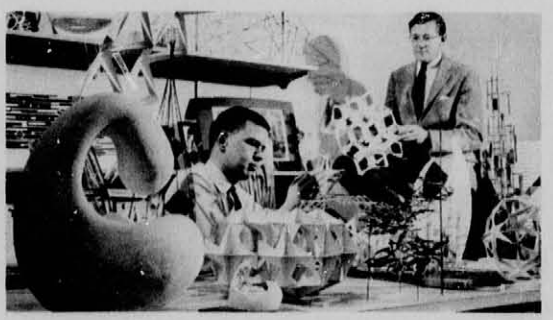
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SENIOR SEMINAR IN INTERNATIONAL POLITICS



PIERRE MENDES-FRANCE IN KRESGE AUDITORIUM



STUDIO WORK IN VISUAL ARTS

HUMANITIES FIELDS AND SUBJECTS

FIRST YEAR

First Term

INTRODUCTION TO THE HUMANITIES (21.01)

Second Term

INTRODUCTION TO THE HUMANITIES (21.02)

SECOND YEAR

First Term

MODERN WESTERN IDEAS AND VALUES (21.03)

Second Term

MODERN WESTERN IDEAS AND VALUES (21.04)

THIRD AND FOURTH YEARS

Any one of the following combinations of subjects may be taken without the approval of a humanities adviser. Other combinations are not prohibited but must be specifically approved by a humanities adviser. Subjects indicated by a dagger (†) may be taken as a single subject to satisfy the distributional requirement.

FIELD ONE: HISTORY

Any three of the following:

THE UNITED STATES: MAKING OF THE NATION, 1760–1865 (21.41)†
THE UNITED STATES: INDUSTRIAL AND WORLD POWER, 1865–1960 (21.42)†
AMERICAN ECONOMIC HISTORY (21.43)†
ECONOMIC LEADERSHIP IN THE INDUSTRIAL WORLD (21.44)†
AMERICAN INTELLECTUAL HISTORY (21.46)†
TECHNOLOGY AND ECONOMIC GROWTH (21.48)†
MODERN EUROPE, 1500–1815 (21.51)†
MODERN EUROPE, 1815–1960 (21.52)†
THE REVOLT OF ASIA (21.53)†
RUSSIAN REVOLUTION AND THE SOVIET UNION (21.54)†
HISTORY OF ENGINEERING (21.55)†
HISTORY OF ENGINEERING (21.56)†
PROBLEMS IN MODERN INTELLECTUAL HISTORY: FREUD (21.58)†
SPECIAL TOPICS IN HISTORY (21.591)
SPECIAL TOPICS IN HISTORY (21.592)

FIELD TWO: PHILOSOPHY

Any three of the following:

PHILOSOPHICAL PROBLEMS AND SYSTEMS I (21.61)†
PHILOSOPHICAL PROBLEMS AND SYSTEMS II (21.62)†
HISTORY OF PHILOSOPHY: ETHICS (21.63T)†
CLASSICAL PHILOSOPHY (21.65)†
PHILOSOPHIES AND RELIGIONS OF THE EAST (21.67)†
MAJOR RELIGIONS OF THE WEST (21.68)†
SYMBOLIC LOGIC (21.69T)†
MORAL PHILOSOPHY (21.70T)†
PHILOSOPHY OF HISTORY (21.71)†
PHILOSOPHY IN LITERATURE (21.72)
PHILOSOPHY OF THE ARTS (21.73)†
METAPHYSICS (21.74)
PROBLEMS IN CONTEMPORARY PHILOSOPHY (21.76T)†
HISTORY OF POLITICAL AND SOCIAL THOUGHT (21.77)†
POLITICAL AND SOCIAL PHILOSOPHY (21.78)†
NATURE OF MAN (21.79)†
EXISTENTIALISM (21.80)†
SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS (21.81)†
SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT (21.82)
PHILOSOPHY OF SCIENCE (21.83)
TOPICS IN THE HISTORY AND PHILOSOPHY OF SCIENCE (21.84)
COSMOLOGY — OLD AND NEW PROBLEMS (21.85)
PROBLEMS OF MODERN SCIENCE IN THE HISTORICAL PERSPECTIVE (21.86)
SPECIAL TOPICS IN PHILOSOPHY (21.891)
SPECIAL TOPICS IN PHILOSOPHY (21.892)

FIELD THREE: LITERATURE

INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
LITERARY CRITICISM (21.12)
THE EPIC (21.13)
THEATRE ARTS: ELEMENTARY STAGECRAFT AND PRODUCTION STUDIES (21.15T)
TRAGEDY AND MODERN DRAMA (21.16)
SHAKESPEARE (21.17)
NON-WESTERN LITERATURE (21.18)
MAJOR WRITERS OF THE ENGLISH RENAISSANCE (21.19T)
THE BIBLE (21.20)
DOSTOEVSKY, TOLSTOI AND MODERN RUSSIAN LITERATURE (21.21)
THE NATURE OF POETRY (21.22)
MODERN POETRY (21.23)
THE NATURE OF THE COMIC (21.24)
THE MODERN NOVEL (21.25)
ENGLISH AND CONTINENTAL LITERATURE OF THE NINETEENTH CENTURY (21.26T)
THE SHORT NOVEL (21.27)
EIGHTEENTH CENTURY LITERATURE (21.29)
AMERICAN FOLKLORE (21.31)
LITERATURE AND SOCIETY (21.33)
MODERN AMERICAN LITERATURE (21.34)
SPECIAL TOPICS IN LITERATURE (21.391)
SPECIAL TOPICS IN LITERATURE (21.392)
DANTE I (23.87)
DANTE II (23.88)

FIELD FOUR: MODERN LANGUAGES

Group A — German

INTERMEDIATE GERMAN (23.14T)
or
INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
THE ROMANTIC ERA AND NINETEENTH CENTURY REALISM (23.15T)†
NATURALISM, EXPRESSIONISM — ERA OF THE GREAT NOVEL (23.16T)
GREAT BOOKS AND AUTHORS IN GERMAN LITERATURE (23.20)†
CONTEMPORARY GERMAN LITERATURE (23.21T)

Group B — French

CONVERSATIONAL FRENCH (23.54T)
or
INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
FRENCH LITERATURE OF THE THIRD REPUBLIC (23.56)†
FRENCH LITERATURE: CLASSICISM AND THE ENLIGHTENMENT (23.59T)†
FRENCH LITERATURE: ROMANTICISM AND REALISM (23.61T)
CONTEMPORARY FRENCH LITERATURE (23.62T)

Group C — Russian

INTERMEDIATE RUSSIAN (23.94)
or
INTRODUCTION TO LITERATURE (21.11)†
plus any two of the following:
GREAT BOOKS AND AUTHORS IN RUSSIAN LITERATURE (23.95)
MODERN RUSSIAN LITERATURE (23.96)†
SOVIET LITERATURE AND THE WEST (23.98)

Group D — Comparative Literature

DANTE I (23.87)
DANTE II (23.88)
plus any literature subject

FIELD FIVE: MUSIC

INTRODUCTION TO MUSIC (21.91)†
and
WESTERN MUSIC FROM THE MIDDLE AGES TO THE BAROQUE (21.92)
plus one of the following:
WESTERN MUSIC IN THE CLASSIC ERA (21.93)
WESTERN MUSIC IN THE ROMANTIC ERA (21.94)
TWENTIETH CENTURY MUSIC (21.95)
THE STRING QUARTETS OF BEETHOVEN (21.96)
THE OPERA (21.98)

FIELD SIX: ECONOMICS

ECONOMIC PRINCIPLES I (14.01)†
and
ECONOMIC PRINCIPLES II (14.02)
and one of the following:
PRICES AND PRODUCTION (14.03)
INDUSTRIAL ORGANIZATION AND PUBLIC POLICY (14.04)
ECONOMIC FLUCTUATIONS AND GROWTH (14.05)
STRUCTURE OF THE AMERICAN ECONOMY (14.06)
COMPARATIVE ECONOMIC SYSTEMS (14.07)
ECONOMIC PROBLEMS SEMINAR (14.09)
ECONOMIC GROWTH AND DEVELOPMENT (14.10T)
ECONOMICS OF INNOVATION (14.21)
MONETARY AND BANKING POLICY (14.40)
PUBLIC FINANCE (14.43)
INTERNATIONAL TRADE (14.54)

FIELD SEVEN: POLITICAL SCIENCE

Any three of the following:

INTERNATIONAL RELATIONS (14.51)†
PRINCIPLES AND PROBLEMS OF AMERICAN DIPLOMACY (14.52)
SEMINAR IN INTERNATIONAL POLITICS (14.53)
CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT (14.57)
THE AMERICAN POLITICAL PROCESS (14.91)†
COMPARATIVE POLITICAL SYSTEMS (14.92)†
SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (14.93)
GOVERNMENT, POLITICS, AND TECHNOLOGY (14.94)
POLITICS, SOCIETY, AND POLICY MAKING (14.95)
INFLUENCES ON POLICY DECISIONS (14.96)
STRUCTURE OF URBAN LIFE (14.99)*
HISTORY OF POLITICAL AND SOCIAL THOUGHT (21.77)†
POLITICAL AND SOCIAL PHILOSOPHY (21.78)†

FIELD EIGHT: LABOR RELATIONS

Group A

ECONOMIC PRINCIPLES I (14.01)†
or
ORGANIZATION AND COMMUNICATION IN GROUPS (14.73)†
and
LABOR RELATIONS (14.63)†
and
LABOR ECONOMICS AND PUBLIC POLICY (14.64)

Group B

LABOR RELATIONS (14.63)†
and
LABOR ECONOMICS AND PUBLIC POLICY (14.64)
and
LABOR PROBLEMS SEMINAR (14.69)

FIELD NINE: PSYCHOLOGY

INTRODUCTORY PSYCHOLOGY (14.70)†
plus any two subjects, at least one in Group A:

Group A

PSYCHOLOGY OF LANGUAGE AND COMMUNICATION (14.77)
LEARNING (14.79)
PSYCHOLOGY OF PERCEPTION (14.81)
PSYCHOLOGY OF MOTIVATION (14.82)

Group B

THEORIES OF PERSONALITY (14.84)
SOCIAL PSYCHOLOGY (14.85)
BEHAVIOR IN GROUPS (14.86)
MASS COMMUNICATION (14.87)

FIELD TEN: VISUAL ARTS

Any three of the following, providing both groups are represented

Group A

VISUAL DESIGN PROBLEMS (4.031)†
VISUAL DESIGN PROJECTS (4.032)

Group B

ARCHITECTURE OF CITIES (4.61)†
INTRODUCTION TO ART AND ARCHITECTURE (4.65)†
MODERN ART AND ARCHITECTURE (4.66)†

* Accepted as two term subjects in the humanities and social sciences.

(*text continued from page 39*)

Students with insufficient training or other language handicaps are urged to take advantage of small-group remedial instruction; for those who are seriously deficient such instruction is required.

For students with suitable preparation, special sections of the four basic subjects are conducted in French by the Department of Modern Languages.

Students in the Schools of Architecture, Engineering, Industrial Management, and Science take a concentration of three humanities or social science subjects in one of ten fields, and a fourth or distributional subject in another field; these subjects are usually taken in the third and fourth years. The fields in which they are grouped are: History, Philosophy, Literature, Modern Languages, Music, Economics, Political Science, Labor Relations, Psychology, and Visual Arts.

The humanities field is selected on a basis of particular interest, except that students enrolled in Shipping and Shipbuilding Management (Course XIII-B) or in Industrial Management (Course XV) may not select either Economics or Labor Relations, and those in Architecture (Course IV-A) may not select Visual Arts.

The subject offerings are described on the next pages. At least some of the work in each concentration must be of higher than elementary level. Although elementary language subjects may not be counted as junior-senior humanities, qualified students are encouraged to build on previous training in modern languages by taking subjects in French, German, or Russian literature.

ECONOMIC PRINCIPLES I (14.01) is a humanities subject which must be taken by all undergraduates in the Schools of Architecture and Industrial Management; and by all in the School of Engineering except those in Chemical Engineering (Course X). It may be taken either as the distributional subject or as part of an appropriate three-term concentration.

Military Science, Air Science, and Naval Science

The general object of the Reserve Officers' Training Corps is to qualify students for positions of leadership in time of national emergency and to provide officers for the United States armed services.

An Army, an Air Force, and a Naval R.O.T.C. detachment have been authorized for this purpose at M.I.T.

THE ARMY R.O.T.C. PROGRAM

The Army R.O.T.C. program at M.I.T. has been established to qualify graduates for commissions as reserve or regular officers in the United States Army in the five following technical branches: Corps of Engineers, Signal Corps, Ordnance Corps, Chemical Corps, and Quartermaster Corps. The program is divided into two parts, the Basic Course and the Advanced Course. Texts, reference books, and equipment are furnished to all cadets without charge.

Basic Course

Regularly enrolled students between 14 and 25 years of age who are citizens of the United States and meet the physical and moral standards prescribed by the Department of the Army are eligible for admission to the R.O.T.C. Basic Course. This course covers the first two years of the program. It provides students with a fundamental knowledge of the organization, functions, and mission of the Army and familiarizes them with the general tactics and techniques employed in land warfare. The subjects included in the Basic Course are: MS11, MS12, MS21, and MS22. Constructive credit may be awarded by the Professor of Military Science for all or a portion of the Basic Course for junior division R.O.T.C. and/or prior military service. The Basic Course subjects have two hours of recitation and one hour of drill per week (2–1–0). Uniforms are issued to the students for wear at drill formations.

Elective Credit

All students completing the Army R.O.T.C. Basic Course will earn twelve units of First-Year Elective credit. Elective credit is not given for the Advanced Course.

Advanced Course

Study in the tactics and techniques of the Corps of Engineers, Signal Corps, Ordnance Corps, Chemical Corps, and Quartermaster Corps is given in the Advanced Course. The objective of this program is to qualify students for commissions in the reserve or regular components of one of these technical branches of the Army. Credit for the Basic Course is normally prerequisite for admission into the Advanced Course.

(*text continues on page 44*)

ARMY R.O.T.C. ELECTIVE SUBJECTS

Subject name and number		Semester hours	Corps of Engineers	Signal Corps	Ordnance Corps	Chemical Corps	Quartermaster Corps
GEOTECHNICAL SCIENCE	1.01	3.5	•				•
FLUID DYNAMICS	1.05	4	•			•	
MECHANICS OF SOLIDS I	2.01	3	•	•	•	•	•
MECHANICS OF SOLIDS II	2.02	3	•	•	•	•	•
STRENGTH OF MATERIALS	2.081	3	•	•	•	•	•
HEAT ENGINEERING	2.42	3	•	•	•	•	•
or							
HEAT ENGINEERING	2.43	3	•	•	•	•	•
ENGINEERING DESIGN	2.731	4.5	•	•	•	•	•
INTERNAL COMBUSTION ENGINES	2.792	3	•	•	•	•	•
MACHINE TOOL FUNDAMENTALS	2.862	2.5	•	•	•	•	•
ENGINEERING MATERIALS	3.14	5	•	•	•	•	•
MATERIALS SCIENCE I	3.31	5.5	•	•	•	•	•
ORGANIC CHEMISTRY I	5.41	4	•		•	•	•
ORGANIC CHEMISTRY II	5.42	4	•		•	•	•
PHYSICAL CHEMISTRY I	5.61	4	•	•	•	•	•
PHYSICAL CHEMISTRY II	5.62	4	•	•	•	•	•
INTRODUCTORY CIRCUIT THEORY II	6.02	4	•	•	•	•	•
FUNDAMENTALS OF ELECTRICAL ENGINEERING	6.18	4	•	•	•	•	•
GENERAL BIOLOGY I	7.01	3				•	•
and							
GENERAL BIOLOGY LABORATORY I	7.011	1.5				•	•
GENERAL BIOLOGY II	7.02	3				•	•
and							
GENERAL BIOLOGY LABORATORY II	7.021	1.5				•	•
PHYSICS	8.04	4.5	•	•	•	•	•
PHYSICS OF ATOMS AND MOLECULES I	8.05	4	•	•	•	•	•
PHYSICS OF ATOMS AND MOLECULES II	8.06	4	•	•	•	•	•
STATISTICAL MECHANICS AND THERMODYNAMICS	8.07	4	•	•	•	•	•
ELECTRONICS	8.08	4	•	•	•	•	•
INDUSTRIAL CHEMISTRY	10.18	3			•	•	•
MINERALOGY I	12.011	5	•			•	•
PHYSICAL GEOLOGY	12.301	5					•
PETROLEUM GEOLOGY I	12.441	3					•
INTERNATIONAL RELATIONS	14.51	3	•	•	•	•	•
PRINCIPLES AND PROBLEMS OF AMERICAN DIPLOMACY	14.52	3	•	•	•	•	•
LABOR RELATIONS	14.63	3	•	•	•	•	•
INTRODUCTORY PSYCHOLOGY	14.70	3	•	•	•	•	•
ORGANIZATION AND COMMUNICATION IN GROUPS	14.73	3	•	•	•	•	•
SOCIAL PSYCHOLOGY	14.85	3	•	•	•	•	•
COMPARATIVE POLITICAL SYSTEMS	14.92	3	•	•	•	•	•
INTRODUCTION TO INDUSTRIAL MANAGEMENT	15.11	3	•	•	•	•	•
PERSONNEL ADMINISTRATION	15.30	3	•	•	•	•	•
BUSINESS LAW	15.61	3	•	•	•	•	•
PRODUCTION MANAGEMENT	15.71	3	•	•	•	•	•
FLIGHT VEHICLE STRUCTURES II	16.21T	3.5	•	•	•	•	•
PROPULSION	16.53	3			•		
ANALYSIS	18.21	3			•		
ANALYSIS	18.22	3			•		
DESCRIPTIVE METEOROLOGY	19.02	3		•		•	
ENGLISH COMPOSITION	21.002	2	•	•	•	•	•
PUBLIC SPEAKING	21.005	3	•	•	•	•	•
SCIENTIFIC AND ENGINEERING WRITING	21.08	2	•	•	•	•	•

(*text continued from page 42*)

Students in the Advanced Course must complete 12 semester hours of subjects from the list on the next page, according to the branch in which they are enrolled. The programs of Military Science subjects required in the five technical branches are as follows:

CORPS OF ENGINEERS	MS312, MS322, MS412, MS422
SIGNAL CORPS	MS313, MS323, MS413, MS423
ORDNANCE CORPS	MS314, MS324, MS414, MS424
CHEMICAL CORPS	MS316, MS326, MS416, MS426
QUARTERMASTER CORPS	MS318, MS328, MS418, MS428

All subjects include one hour of preparation and either three hours of recitation or two hours of recitation and one hour of drill [(3–0–1) or (2–1–1)].

Students under 27 years of age who have at least two academic years remaining before graduation and who are physically qualified may apply for enrollment. Applicants who pass the physical examination and have the qualities of character and aptitude essential for military leadership are selected for enrollment by the Professor of Military Science.

A student who enrolls in the Advanced Course must sign a deferment agreement and a contract to remain in the Course for two years; both agreement and contract will be canceled if the student withdraws from the Institute. Students in the Advanced Course are also required to attend the R.O.T.C. camp, which is normally scheduled during the last two weeks in June and the month of July following their first year in the Advanced Course; all expenses of attending the camp, including transportation, are paid by the government. Upon graduation students are commissioned as Second Lieutenants and are required to fulfill their military obligation. This may be six months active duty for training and seven and one-half of reserve duty, or two years active duty and four years of reserve duty. Start of active duty may be delayed to allow for pursuit of graduate study.

For those students enrolled in the Advanced Course, M.I.T. receives from the government an allowance of $100 per student, which is applied against the cost of the student's uniform, which is retained by the student upon graduation. Students enrolled receive approximately 90 cents per day subsistence from the date of their enrollment until their graduation, including one summer vacation, except when they are at the R.O.T.C. camp and paid by the government at the rate of $78 per month.

THE AIR FORCE R.O.T.C. PROGRAM

The Air Force R.O.T.C. program is designed to prepare students for commissions in the United States Air Force upon successful completion of an M.I.T. undergraduate Course. The program consists of classroom and laboratory work during the four undergraduate years and one summer training period of four weeks, usually between the junior and senior years, at a United States Air Force Base.

During the first two years the program acquaints students with military and Air Force history, technological advances, and current research and development activities. Leadership training is also begun. During the last two years, emphasis is placed on personal development. Students increase their ability to communicate their thoughts to others both orally and in writing. Subjects in GLOBAL GEOGRAPHY (AS42T) and INTERNATIONAL RELATIONS (14.51) deepen the students' understanding of world affairs. Understanding of people and interpersonal relationships are also stressed. Students increase their leadership ability by assuming positions of responsibility in the Cadet Corps at M.I.T. and in the required summer camp. To insure that they will keep abreast of developments in the Air Force, students continue to receive information on technological advances.

While in an undergraduate status, Air Force R.O.T.C. students are furnished, free of charge, all text and reference books, uniforms, and equipment required for Air Science study. During the last two years they are paid a subsistence allowance of 90 cents per day; they receive reimbursement for travel to and from summer camp, and while there are paid at the rate of $78 per month.

Incoming freshmen selected for enrollment in A.F.R.O.T.C. are required to sign a statement that they intend to complete four years of Air Science training. At the beginning of the junior year each student is required to sign a formal agreement that he will complete Advanced A.F.R.O.T.C. and accept a commission as a Second Lieutenant in the United States Air Force when he has been granted his degree from M.I.T. The term of commitment after commissioning will vary depending upon the professional area chosen. For those entering research and development, engineering, or any other nonflying field, the term of service is four years; if the student is physically qualified and desires to

become a pilot or navigator, the required term of service is five years.

Students who qualify for an Honors Course or who take a Cooperative Course will be accommodated in the Air Science program. Certain students who desire to do graduate work after completion of a Bachelor's degree may request a delay in reporting for active duty until the completion of the graduate work. Furthermore, a few selected students may take graduate work at Air Force expense, immediately after commissioning.

Eligibility Requirements

To be eligible for the Air Force R.O.T.C. program a student must be:

1. A male citizen of the United States.
2. Physically qualified for commission in the United States Air Force in accordance with existing Air Force regulations.
3. Not under 14 years of age; and upon graduation not more than 26 years and 6 months of age for flying training and 28 years of age for all other categories.
4. Planning to pursue work at M.I.T. leading to at least a Bachelor's degree in any Course offered by the Institute.
5. Willing to sign a formal agreement at the beginning of the junior year which obligates him to remain in the R.O.T.C. program for the two final years, to accept a commission, and to serve the required period in the Air Force upon graduation.

The Four-Year Program

Students in the Air Force R.O.T.C. program must, while completing degree requirements in one of the M.I.T. Courses, take INTERNATIONAL RELATIONS (14.51) and the following required subjects in Air Science:

FIRST YEAR

First Term

AS 11 EVOLUTION OF WARFARE (3–1–5)
(M.I.T. First-Year Elective Credit)

Second Term

AS 12 FOUNDATIONS OF AIR POWER (3–1–5)
(M.I.T. First-Year Elective Credit)

SECOND YEAR

First Term

AS 21T U.S. AIR FORCE WEAPON SYSTEMS (0–1–0)
(No M.I.T. credit)

Second Term

AS 22T AEROSPACE RESEARCH VEHICLES AND SYSTEMS (0–1–0)
(No M.I.T. credit)

THIRD YEAR[1]

First Term

AS 31 RESEARCH AND DEVELOPMENT IN THE U.S. AIR FORCE (0–1–0)
(No M.I.T. credit)

Second Term

AS 32 PREPARATION FOR COMMAND AND STAFF POSITIONS (0–1–0)
(No M.I.T. credit)

FOURTH YEAR[1]

First Term

AS 41T PRINCIPLES AND TECHNIQUES OF LEADERSHIP (3–1–5)
(M.I.T. elective credit for 9 units)

Second Term

AS 42T GLOBAL GEOGRAPHY (3–1–5)
(M.I.T. elective credit for 9 units)

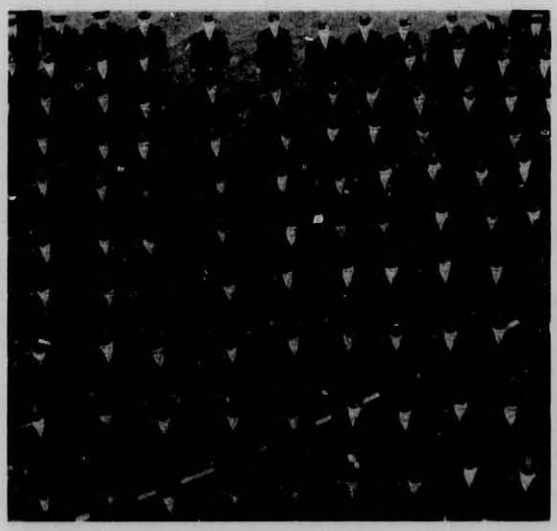
[1] 14.51 INTERNATIONAL RELATIONS (3–0–5) must be taken in either the third or fourth year and will be accepted as credit toward the Bachelor's degree.

Application Procedure

Eligible students should apply for admission to the Air Force R.O.T.C. only after they have been notified of admission to the Institute. Application should then be made directly to the Professor of Air Science either by mail or by personal visit as soon as possible and not later than September 11. Applications received after this date will be considered in special cases. Further information, including physical standards, will be forwarded upon receipt of an initial application.

Selection Procedure

Selection from among eligible applicants will be made by the Professor of Air Science after considering and evaluating such factors as past academic record, leadership displayed in high school activities, personal motivation, and potential officer capabilities. Of primary importance will be the results of a physical examination, administered on the campus by the United States Air Force at no cost to the applicant, on the Tuesday and Wednesday of Freshman Week. All applicants will be informed of their status as soon as possible.



THE NAVAL R.O.T.C. PROGRAM

The purpose of the Naval R.O.T.C. program is to provide instruction and training in essential naval science subjects, which, when coupled with the prescribed M.I.T. engineering curricula, will qualify selected male students for commissions as Naval Reserve Officers in the restricted line category (engineering duty only).

The M.I.T. Navy unit is the only one of the fifty-three nation-wide Naval R.O.T.C. Programs designed to produce solely "engineering duty only" officers. Graduates of this program may serve their obligatory active duty as engineering officers aboard ship, in naval shipyards, or in other technical assignments. Students may apply for the Navy Nuclear Power Program or request that they be commissioned in the Civil Engineer Corps of the Navy, if qualified. Postgraduate work leading to a Master's degree prior to active duty assignment is allowed when the quality of the student's work and the technical specialty involved warrant. Selected Master of Science candidates can be deferred from active duty to complete work for the doctorate. The work for the advanced degrees need not be taken at M.I.T.

The program of instruction and training consists of three hours of classroom and one hour of laboratory work per week during the freshman and senior years and one hour of lecture per week during the sophomore and junior years. One summer period of approximately five weeks is devoted to practical engineering training at sea aboard a naval ship. This period is scheduled during the summer between the third and fourth academic years.

While in an undergraduate status, the Naval R.O.T.C. student is furnished all necessary text and reference books required for the naval science course, all uniforms and uniform equipment, and in addition is paid a standard ration allowance of 90 cents per day during his third and fourth academic years. Transportation to and from the port of embarkation for the summer cruise is furnished by the Navy, and the student is paid at the current rate of $78 per month while on the cruise. Upon completion of the program and receipt of a Bachelor of Science degree from M.I.T., the student is commissioned as an ensign (EDO), U.S. Naval Reserve; he is ordered to active duty in an engineering duty billet either afloat or ashore for a period of two years, unless he plans to attend graduate school, as noted above. At the end of this two-year period he may be released to inactive duty, but he must retain his commission as a Reserve Officer for a total of six years from the date of its original acceptance.

Eligibility Requirements

To be eligible for the Naval R.O.T.C. program, a student must be:

1. A male citizen of the United States.
2. Age 17 to 21 by July 1 of his entering year. (This age requirement may be lowered to 16 for outstanding students.)
3. Unmarried, never have been married, and willing to remain unmarried until commissioned.
4. Physicaliy qualified in accordance with the standards for entrance to the United States Naval Academy, except that visual acuity as low as 20/100 correctable to 20/20 by the use of lenses is acceptable.
5. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any Course except the following: Cooperative Course in Mechanical Engineering (II-B), Architecture (IV-A), Cooperative Course in Electrical Engineering (VI-A), Life Sciences (VII), Chemical Engineering Practice (X-B), Geology and Geophysics (XII and XII-A), Economics, Politics, and Engineering or Science (XIV-A and XIV-B), and Cooperative Course in Aeronautics and Astronautics (XVI-B).
6. Willing to sign a contract with the Navy which obligates the student, after completing the requirements for a commission, to fulfill the following additional requirements: to accept a commission, to serve on active duty for a period of two years subsequent to graduation, and to retain the commission for a period of six years from the date of original acceptance.

The Four-Year Program

Students in the Naval R.O.T.C. program must, while completing degree requirements in one of the acceptable Courses, take the following required subjects in Naval Science:

FIRST YEAR

First Term

NS 11 ORIENTATION AND SEA POWER (3–1–5)
(M.I.T. First-Year Elective Credit)

Second Term

NS 12 ORIENTATION AND SEA POWER (3–1–5)
(M.I.T. First-Year Elective Credit)

SECOND YEAR

First Term

NS 21 NAVAL GUIDED MISSILES (1–0–0)
(No M.I.T. credit)

Second Term

NS 22 NAVAL GUIDED MISSILES (1–0–0)
(No M.I.T. credit)

THIRD YEAR

First Term

NS 31 NAVAL NUCLEAR PROPULSION (1–0–0)
(No M.I.T. credit)

Second Term

NS 32 NAVAL NUCLEAR PROPULSION (1–0–0)
(No M.I.T. credit)

FOURTH YEAR

First Term

NS 41 NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP (3–1–5)
(M.I.T. elective credit for 9 units)

Second Term

NS 42 NAVAL INDUSTRIAL MANAGEMENT AND LEADERSHIP (3–1–5)
(M.I.T. elective credit for 9 units)

Application Procedure

Eligible students should apply for admission to the Naval R.O.T.C. program as soon as they have been notified of their admission to the Institute. Applications should be made directly to the Commanding Officer of the Naval R.O.T.C. Unit, either by mail or by personal visit by Registration Day or as soon as possible thereafter.

The Naval R.O.T.C. program at M.I.T. is not open to students selected under the nationwide Navy scholarship program known as the Regular N.R.O.T.C. or Holloway Plan. Further inquiries regarding the M.I.T. program should be addressed to the Commanding Officer, N.R.O.T.C. and Naval Administrative Unit, M.I.T.

Costs

The Institute is an independent, endowed institution; the tuition of $1,500 per year paid by each student covers less than half the cost of facilities and teaching; the balance is met by income from endowment and by gifts.

Basic Expenses

The following list gives an estimate of the average student's basic costs for the academic year 1961–62 at M.I.T.:

Tuition	$1,500[1]
Board	610[2]
Room	370
Books and materials	100
Medical insurance	55[3]
	$2,635

[1] Tuition will be increased to $1,700, effective with the 1962 Summer Session.

[2] This figure does not include the cost of board during vacation periods.

[3] This figure covers a twelve-month period.

Additional Fees

In addition to the above costs, a reasonable allowance (probably at least $200 per academic year) should be made for such expenses as clothes, laundry, personal necessities, and transportation. This total varies according to individual tastes and requirements.

During the freshman year there are certain non-recurring expenses such as drawing equipment and slide rules, for which $40 should be allowed. In addition, there are deposits to cover breakage, repair of military uniforms, and laboratory equipment. These and other fees and expenses are described in detail in Section 1 of this Catalogue.

It is important that each student make an accurate estimate of his expenses, including the basic costs given above, the variable personal expenses, and the needs for transportation. This estimate should be considered carefully in the light of his available funds.

Financial Aid for Undergraduates

Three forms of financial aid available to M.I.T. undergraduates — scholarships, loans, and part-time campus work — are administered under a coordinated program of financial aids, the purpose of which is to assist well-qualified students who have limited funds and resources.

SCHOLARSHIPS

All incoming and undergraduate students may apply for scholarship aid. Except for those students who enter under a two-degree plan, students who have attended another college are not eligible for scholarship aid until they have satisfactorily completed one year's work at M.I.T. Applications for scholarships are thoroughly considered by the Student Financial Aid Committee, which makes all awards.

For Entering Freshmen

For students of limited means who need help in meeting their expenses, the Institute has available a substantial number of scholarship grants (full and part tuition), as well as awards from the M.I.T. loan funds, for the freshman year. Approximately one quarter of the entering class receives some aid from this source, which includes several four-year grants, based on demonstrated need, sponsored by several

corporations, foundations, and industrial organizations; among these are the Alfred P. Sloan and the Alumni Fund National Scholarships. Applications for any freshman grant must be filed before January 15. (See Appendix A for complete details.)

For Upperclassmen

After one year of residence any undergraduate may apply for scholarship aid. Applications are made to the Student Financial Aid Committee. Grants are made on an annual basis dependent not only on academic excellence but also on demonstrated need.

LOANS

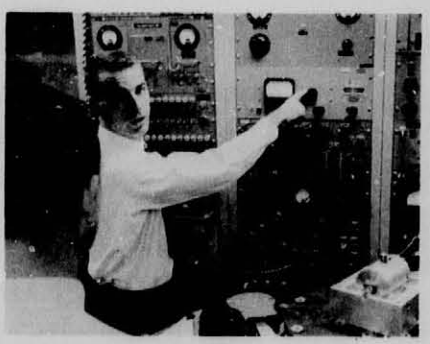
The Technology Loan Fund is available on application to students with satisfactory academic records. Awards from this fund may be in addition to any scholarship grants. Complete details are given in Appendix A.

STUDENT EMPLOYMENT

The Office of Student Personnel is maintained to help students who wish to help themselves meet part of their expenses by earnings in on-the-campus jobs. The requirements of the Institute curriculum are such that only a limited amount of time may be given to employment, and prospective students are advised to have sufficient funds to cover the expenses of the first year at least. The average that can be earned through part-time employment does not usually exceed $225 per term. This amount may be realized in a number of jobs on the campus, such as those in the dining services, the library, and residence halls. Some outside jobs are available in Boston and Cambridge, but these are likely to be limited by the difficulty in scheduling them without conflict with academic appointments.









Undergraduate Admission to M. I. T.

By far the largest number of students enter M.I.T. as members of the freshman class, following completion of secondary school studies. But each year a limited number of students whose previous studies at other universities entitle them to advanced standing are accepted for entrance.

First-year students may enter only at the beginning of the first term, which is the Monday prior to the last Monday in September.

ADMISSION FROM SECONDARY SCHOOLS

Under the Institute's policy of stabilized enrollment, the size of the first-year class is limited. Since it is expected that the number of applications will exceed the number that can be accommodated, the Faculty Committee on Admissions will exercise discretionary powers of selection.

Selection of Applicants

Preference will be accorded applicants whose evidence of academic fitness and of professional promise indicates that they are particularly qualified to pursue Institute Courses with success. It is the desire of the faculty to admit only those candidates who possess qualities of character and intellect which indicate their adaptability to an academic environment and who show promise of development into useful and forceful citizens.

Academic Preparation

The better public, parochial, and independent secondary schools in the United States and equivalent schools in other countries will, in general, provide suitable preparation for the student who takes full advantage of the opportunities which such schools afford.

Students should bear in mind that the wider their intellectual development and the more extensive their attainments, the greater will be the advantages they may expect to gain from study at the Institute. The preparatory course should be a broad one, not confined to technical subjects.

Attention is called particularly to the necessity for thorough preparation in English and mathematics. An applicant's training in English should enable him to read with intelligence and sensitivity and to express his 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.

Each applicant is required to have completed the following specific preparatory subjects; the figures in parentheses represent the usual "unit" rating, a unit being a full year's study in a secondary school subject taken four or five times a week:

English (3)
Algebra (2)
Plane Geometry (1)
Physics (1)
Trigonometry (½)

English is normally studied through four years, and this is counted as three units. In some states, algebra is completed in 1½ years; this will satisfy the algebra requirement for candidates from those states. The plane geometry requirement may be met either by a course of the traditional type or by a one-year course which is mainly devoted to plane geometry but which includes some work in analytic geometry, solid geometry, or other fields, as suggested by the Commission on Mathematics of the College Entrance Examination Board. The inclusion of some topics from solid geometry is particularly recommended.

In addition to the subjects specifically required, the applicant will normally have completed 7½ additional units, or their equivalent, in secondary school studies; no limitations are imposed in the choice of these elective subjects. In the selection of the entering class the Committee will be guided by the quality of the applicant's work and by his apparent promise on grounds of intellect and character, rather than by his choice of electives.

It is nevertheless recommended, though not required, that the elective subjects include a year of chemistry, as preparation for the first-year chemistry subject at the Institute, and one or more year's study of history.

While there is no language requirement for admission, the study of modern foreign languages in secondary school is obviously desirable and is recommended. The choice of languages should be guided by the educational opportunities open to each student and by the nature of his probable future work.

A student who has ties with a particular foreign country, or who expects to develop such

ties, might well study the language of that country. Those who look forward to advanced work in research or design in a scientific or engineering field will almost certainly need a knowledge of German, Russian, or French, since there is an extensive and important technical literature in each of these languages.

In unusual cases, students of exceptional promise may be considered for admission without having fulfilled all of the stated requirements.

Application Procedure

A Preliminary Application, on a form which may be obtained from the Director of Admissions, may be filed as early as desired in advance of the anticipated date of entrance. This assures that the applicant will receive Final Application forms at the proper time, as well as any announcements which may be issued.

The Final Application form is sent in the fall preceding the desired date of entrance to candidates who have filed Preliminary Application forms.

Candidates should complete the Final Application and submit it with a non-returnable fee of $10 (required only of students who are citizens of the United States and Canada). A check or money order, payable to W. A. Hokanson, Bursar, is preferred.

Interviews

Each applicant for admission to the freshman class is expected to have a personal conference either in the Admissions Office or with a designated member of the M.I.T. Educational Council near his home. Council members are alumni who have been selected for their ability to represent M.I.T. and for their interest in and liking for young people. They welcome the opportunity to meet students interested in M.I.T. and to help them in their educational plans.

Each applicant will be referred for a personal conference to a member of the Council at the time of receipt of his Preliminary Application in the Admissions Office. This personal conference is an essential part of the final application and should take place prior to January 15 of the year of entrance.

Counselors will be glad to speak with any applicants at earlier dates for general information and counseling purposes. In such cases another conference should be held after May 1 of the year immediately preceding that in which the applicant wishes to enter.

Applicants are welcome at the Admissions Office Mondays through Fridays between 9 and 5; it is not necessary to make an appointment. Visitors may wish to plan their time to include a student-guided tour of the campus, available at 10 and 2 o'clock each day that the Admissions Office is open.

Entrance Examinations

All candidates are required to take a series of tests given by the College Entrance Examination Board. This includes the following tests: in the morning, the Scholastic Aptitude Tests; in the afternoon, three one-hour achievement tests: (1) Advanced Mathematics, (2) English Composition, and (3) either Physics or Chemistry.

The 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 by writing directly to the Board.

Apply to the College Entrance Examination Board, Box 592, Princeton, New Jersey. (Residents of Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming, Alberta, British Columbia, Mexico, Australia, Pacific Islands, Japan, and Formosa should apply to the College Entrance Examination Board, Box 27896, Los Angeles 27, California.)

Candidates may choose any date they wish or divide the tests among two or more dates in the same or in different years. A candidate should plan to have completed the required series of tests not later than the January test date of his senior year. A student taking physics or chemistry in his junior or eleventh-grade year should take either the Physics or the Chemistry Achievement Test, along with the Scholastic Aptitude Test, in May of that year. The Advanced Mathematics Achievement Test is normally taken in January of the last year in school. The Board should be requested to send the scores directly to the Institute.

Candidates who complete the tests in January and have submitted all other required material will be notified about admission to M.I.T. in March.

Early Decisions on Applications

M.I.T. requires a candidate to submit a complete application before considering him for admission; there is no "early decision" plan in the usual sense. The Institute believes the

freshman class is selected with most fairness to the candidates by comparing them with each other on the basis of their records through the first half of their senior year. However, if a student takes the required College Board tests before his senior year, the Committee on Admissions will review his application as soon as it is complete. If the student's test scores, school grades, and other qualifications are so excellent that he will clearly be acceptable later, the Committee will offer him admission immediately; if it feels that it should compare his application with those of other candidates, it will hold his application until the usual time. A student who seeks early consideration in this way is free to file applications at other colleges and, if offered admission at M.I.T., is not required to reply to the Institute before May 1, the colleges' common reply date. A student interested in his academic standing relative to M.I.T.'s standards should consult the published M.I.T. Freshman Class Statistics, available in the guidance office at his school or through the M.I.T. Admissions Office.

ADVANCED PLACEMENT

M.I.T. has always encouraged students to move ahead academically according to their capabilities; it offers three procedures by which students entering from secondary school may go directly into a subject at an advanced level: by the College Entrance Examination Board Advanced Placement Program; by college transcript; by Advanced Standing Examination at M.I.T.

Qualified juniors and seniors who take college-level subjects offered in their schools in cooperation with the College Entrance Examination 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, test papers, and reports from the school to M.I.T. Credit for M.I.T. subjects, and consequent advanced placement, is given on the basis of a high achievement in the tests. The student is notified before registration of the credit offered so that he may discuss with his Faculty Adviser an optimum schedule.

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

Students whose advanced study does not follow either of these patterns and who are interested in being considered for M.I.T. degree credit at entrance should write to the Director of Advanced Placement at M.I.T. before August 1 about their studies and should request information about the Advanced Standing Examinations at M.I.T.

A special leaflet concerning Advanced Placement and Degree Credit at M.I.T. is available upon request.

COLLEGE TRANSFERS

Students who have completed one or more semesters with high standing at a recognized college, university, engineering school, or junior college and who are entitled to honorable dismissal may be admitted to M.I.T. by transfer.

Selection of Students

Transfer students' eligibility for admission will be determined by the Committee on Admissions after a review of their records. They will be expected in every case to have completed the academic preparation required of students entering the Institute from secondary schools.

Such applicants should take the test program prescribed above for entering freshmen. The tests may be waived by the Committee on Admissions for applicants who have completed a substantial amount of college-level work in mathematics and science.

Advanced Credit

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

All such credits are provisional and become final only after the student has demonstrated his ability to do satisfactory work in the Course of his choice. Students whose records appear not to warrant advanced credit in a subject may be permitted to demonstrate by passing an advanced standing examination that they are entitled to such credit.

A student in another college contemplating later transfer should plan his program of study to cover the basic subjects of the Course he expects to enter, paying particular attention to mathematics and physics.

Application Procedure

College students considering transfer to the Institute should file a Preliminary Application for Admission with Advanced Standing on a form obtainable from the Admissions Office. The Director of Admissions will advise the applicant of those parts of the regular entrance requirements which he must fulfill and will arrange for the final application material to be sent.

The applicant should then submit the following to the Director of Admissions:

1. A completed Application for Admission with Advanced Standing, indicating all subjects which he will have completed at the time of transfer, and a non-returnable fee of $10. A check or money order, payable to W. A. Hokanson, Bursar, is preferred.

2. A certified transcript of his college record to date, including a statement of honorable dismissal or its equivalent. 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; the applicant's name should be written on each page and each subject indicated by a check mark in the margin. Complete catalogues should not be sent.

As soon as the applicant's status is determined, he will be informed of whether or not he is admitted and how much advanced credit he will be granted. In some cases action may necessarily be deferred until final grades are available.

Applications from students in their first year in college will normally be considered only after the college record for the entire year becomes available.

All remaining questions about 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.

Applicants seeking admission with advanced standing in architecture will be graded in DESIGN in accordance with their performance in their first problem.

Students who have attended another college will not be eligible for scholarship aid until they have satisfactorily completed one year's work at M.I.T.

The Two-Degree Plan

A number of liberal arts colleges grant their Bachelor's degree to students who have attended for three years and who have then gone on to qualify for a Bachelor's degree in engineering, management, or architecture at M.I.T. or a similar institution. A student who plans his three college years carefully to include the requisite mathematics and science, as well as humanities and social science, can usually obtain the Bachelor of Science degree at M.I.T. in two additional years (three for the Bachelor in Architecture).

Students interested in this plan should communicate directly with the college they wish to attend first and secure admission there. Later acceptance at M.I.T. will depend, as with all transfer applicants, on the quality of the college record.

College transfer students are, in general, not eligible for financial aid during their first year of attendance. Exceptions may be made for students of outstanding promise who are designated as members of a two-degree plan by their college and are already receiving financial aid there.

ADMISSION OF FOREIGN STUDENTS

Students of foreign citizenship may start their undergraduate work at the Institute only at the beginning of the September term each year. Applications for admission are submitted to the Committee on Admissions on April 1 of each year. Since the number of available places will be completely filled at the April 1 review, applications received after that date cannot be considered for the first term of that year. However, such applications may be considered for a subsequent year, if requested.

Action cannot be taken on admission until complete application material has been received. Applications accompanied by incomplete credentials will not be considered. The usual $10 application fee is not required of foreign students, except those of Canadian citizenship.

Foreign students should make all arrangements for their financial obligations to M.I.T. and for their entire stay in the United States before leaving their countries.

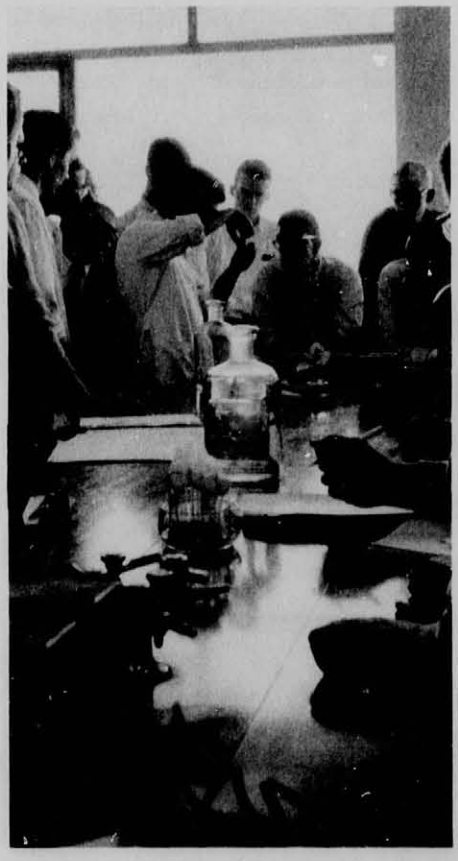
Foreign students who wish to enter the Institute for graduate study should refer to Section 3 of this Catalogue.

Further information about the admission of foreign students is available from the Office of the Adviser to Foreign Students, M.I.T.

ADMISSION OF SPECIAL STUDENTS

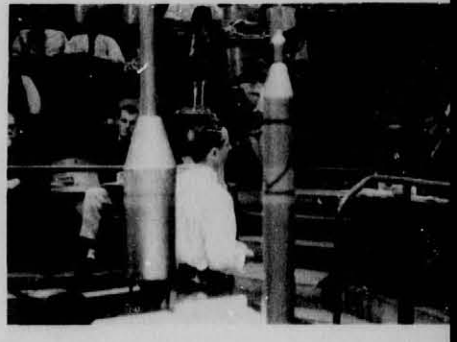
A limited number of undergraduates who wish to carry on special studies and who are not degree candidates may enroll as Special Students. Applications are received by the Director of Admissions, and the application and program of study must be approved by the department(s) principally concerned and by the Director of Admissions. Applicants must present academic credentials of high quality or evidence of professional experience which justifies undertaking the program planned.

The admission of Special Graduate Students is described in Section 3 of this Catalogue.

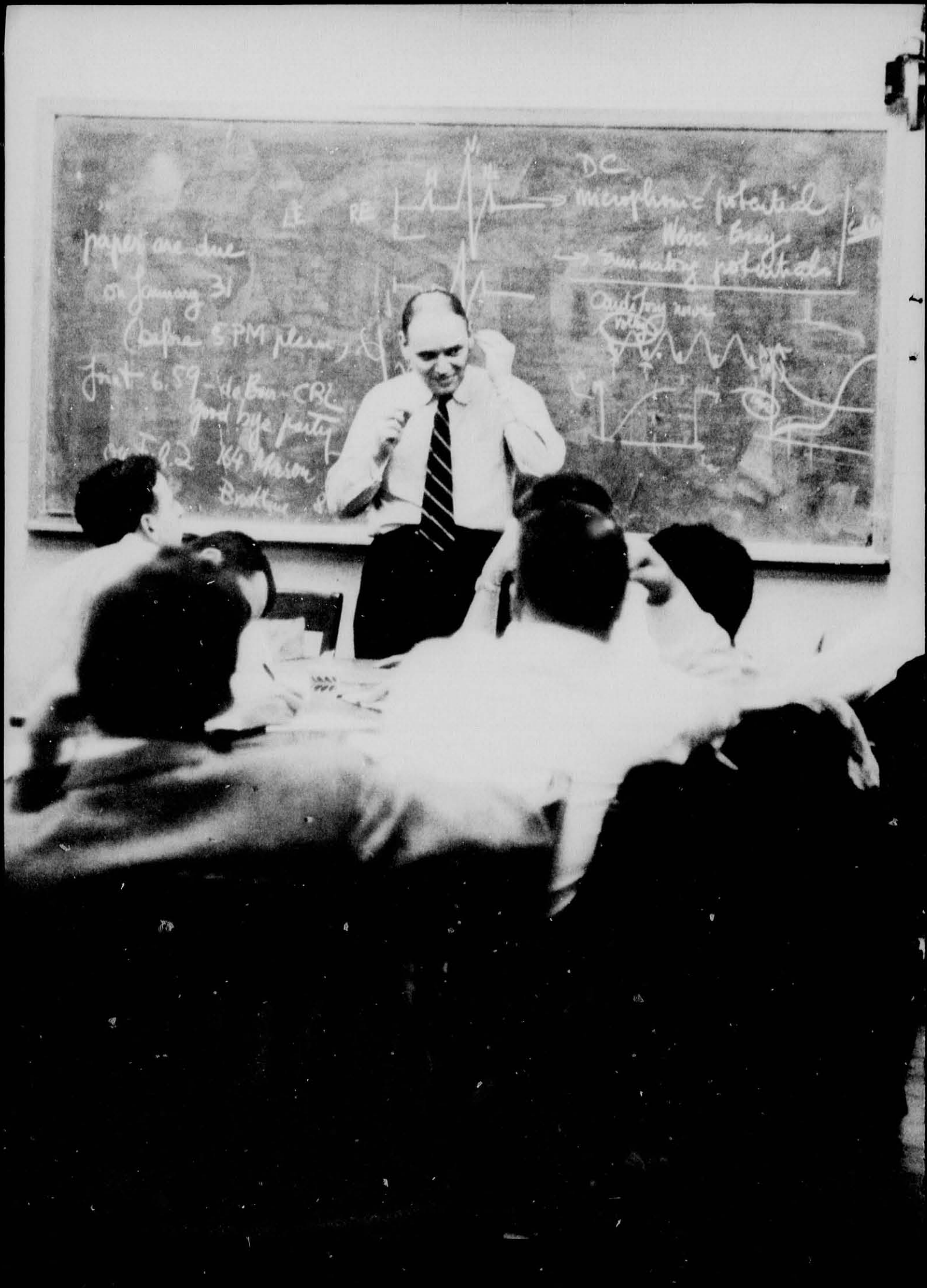











papers are due
on January 31
DC
Microphonic potentials
Wave form
Summating potentials

GRADUATE EDUCATION 3.

THE GRADUATE SCHOOL

HAROLD LOCKE HAZEN, SC.D.
Dean

ERNEST HAMLIN HUNTRESS, PH.D.
Secretary

COMMITTEE ON GRADUATE SCHOOL POLICY

HAROLD L. HAZEN, SC.D.
Dean of the Graduate School, Chairman*

ERNEST H. HUNTRESS, PH.D.
Secretary of the Graduate School, Secretary*

ROLAND B. GREELEY, A.B.
*Director of Admissions**

PATRICK M. HURLEY, PH.D.
*Chairman of the Faculty**

MARTIN A. ABKOWITZ, PH.D.
Professor of Naval Architecture

JAMES M. AUSTIN, SC.D.
Associate Professor of Meteorology

E. CARY BROWN, PH.D.
Professor of Economics

EDUARDO F. CATALANO, M. ARCH.
Professor of Architecture

HAROLD W. FAIRBAIRN, PH.D.
Professor of Geology

TRUMAN S. GRAY, SC.D.
Professor of Engineering Electronics

MORRIS HALLE, PH.D.
Professor of Modern Languages

MYLE J. HOLLEY, JR., S.M.
Professor of Structural Engineering

DAVID N. HUME, PH.D.
Professor of Chemistry

GEORGE F. KOSTER, PH.D.
Associate Professor of Physics

KEVIN A. LYNCH, B.C.P.
Associate Professor of City Planning

HENRY P. McKEAN, JR., PH.D.
Associate Professor of Mathematics

DONALD G. MARQUIS, PH.D.
Professor of Industrial Management

JOHN T. R. NICKERSON, PH.D.
Associate Professor of Food Science and Technology

JOHN T. NORTON, SC.D.
Professor of the Physics of Metals

NORMAN J. PADELFORD, PH.D., LL.D.†
Professor of Political Science

WARREN M. ROHSENOW, D.ENG.
Professor of Mechanical Engineering

DAVID J. ROSE, PH.D.
Professor of Nuclear Engineering

LEON TRILLING, PH.D.
Associate Professor of Aeronautics and Astronautics

DAVID F. WAUGH, PH.D.
Professor of Biophysics

GLENN C. WILLIAMS, SC.D.
Professor of Chemical Engineering

* *Ex officio*
† Appointed by the President

CHAIRMEN OF DEPARTMENT COMMITTEES ON GRADUATE STUDENTS

LEON TRILLING
Aeronautics and Astronautics

LAWRENCE B. ANDERSON
Architecture

DAVID F. WAUGH
Biology

GLENN C. WILLIAMS
Chemical Engineering

DAVID N. HUME
Chemistry

JOHN T. HOWARD
City and Regional Planning

MYLE J. HOLLEY, JR.
Civil Engineering, Sanitary Engineering, Building Engineering and Construction

ROBERT M. SOLOW
Economics and Social Science

DAVID A. HUFFMAN
Electrical Engineering

HAROLD W. FAIRBAIRN
Geology and Geophysics

DONALD G. MARQUIS
Industrial Management

NORMAN LEVINSON
Mathematics

WARREN M. ROHSENOW
Mechanical Engineering

JOHN T. NORTON
Metallurgy

JAMES M. AUSTIN
Meteorology

MORRIS HALLE
Modern Languages

MARTIN A. ABKOWITZ
Naval Architecture and Marine Engineering

MANSON BENEDICT
Nuclear Engineering

SAMUEL A. GOLDBLITH
Nutrition, Food Science and Technology

PHILIP M. MORSE
Physics



The M.I.T. Graduate School

In the Graduate School, faculty members and post-baccalaureate students are associated as a community of scholars sharing common endeavor in advanced professional study and creative work. The Graduate School, as the Institute-wide organization for academic administration of post-baccalaureate study, seeks to promote the best environment for advanced study and for intimate association among creative workers, faculty and students alike, who are extending the boundaries of knowledge in their professions. It brings the common interests of all departments together for mutual support in the achievement of high standards in graduate study and research.

Among the elements which are essential to any graduate school, the qualities of its faculty are central. Faculty strength is needed over a wide range of fields to serve varied student interests. National, indeed international, recognition as a productive scholar and authority in his field is normally expected of the individual faculty member. Satisfaction in his work and in his association with his students characterizes the effective teacher. M.I.T. is proud of its faculty as judged by these criteria.

An outstanding characteristic of graduate education at M.I.T. is the atmosphere of intellectual independence and individual creativity combined with a strong sense of group unity and cooperation. This spirit, permeating the entire Institute, is cherished as a major asset of the Graduate School.

Graduate instruction is further distinguished by an emphasis, throughout the Institute, on a deeper understanding of elementary concepts, a clearer insight in applying fundamental ideas to new problems. Our primary aim is to develop in each student the realization that his intellectual growth and his subsequent success are directly related to the depth of his command of basic principles. Although graduate study is often popularly associated only with a high











degree of specialization, M.I.T. believes that such specialization, while valuable, is secondary to extending mental horizons, producing new orientations, and developing growth in intellectual courage and in depth of understanding. Achieving mastery of basic principles develops the mind as no mere acquisition of specialized knowledge can; it provides the power to attack unsolved problems with success and to explore new areas of knowledge with confidence.

Successful graduate study is closely associated with the ability to organize and express important ideas in clear and simple terms. Therefore graduate students find assignments as teaching assistants rewarding and stimulating as an integral part of their graduate education. These and similar junior staff positions in research also offer the student professional assignments combined with an approach to financial self-sufficiency. At M.I.T., graduate students are in a very real sense junior partners of the faculty in study, in teaching, and in pioneering research. They have the responsibilities of mature students and independent professional workers.

While the graduate student tends normally toward intensive preoccupation with his professional field, M.I.T. encourages breadth of experience as well. Doctoral Minors are occasionally taken in fields entirely unrelated to the Major field. Leaders in many fields give lectures and seminars on the campus. Concerts are frequent, given by both Institute groups and professional performers. Greater Boston is an outstanding intellectual and cultural center. The M.I.T. community has a notably cosmopolitan character: Graduate School enrollment typically includes citizens of sixty foreign countries who together account for about one in every six graduate students. Many graduate students take advantage of these exceptional opportunities for extending interests and understanding to new fields.

Student Organizations and Activities

All graduate students at the Institute are included in the Graduate Student Organization. Its executive body is an elected Council, whose membership includes representatives of all Courses, of the Graduate House, and of off-campus graduate residents. The Organization is concerned primarily with the general welfare of the graduate student body, its social and extra-curricular activities, and its relations with the Institute.

Graduate House residents have a Graduate House Student Organization, which functions autonomously and in a similar way through its Executive Committee.

Graduate students are encouraged to use all of M.I.T.'s extensive athletic facilities; a number of informal teams composed of both undergraduate and graduate students schedule intercollegiate competitions. The Nautical Association, several musical groups, and many other campus organizations described in Section 1 of this Catalogue also welcome graduate student participation.

Organization of the Graduate School

The principal aspects of the Graduate School operation are described in the following paragraphs. A more detailed statement of organization, policies, and procedures is given in the *Graduate School Manual*, a copy of which is sent with each official notice of admission to the Graduate School. Each graduate student is expected to be familiar with this manual.

The Institute faculty is the same for undergraduate and graduate instruction. The officers of the Graduate School are the President of the Institute, the Dean of the Graduate School, the Secretary of the Graduate School, and the Committee on Graduate School Policy, comprised of a faculty member from each department offering graduate degrees. Each department exercises a large measure of responsibility for its graduate program, under a policy established for the Institute as a whole. Under the general responsibility of the Department Head, each department offering graduate degrees has a departmental Committee on Graduate Students, which, with one or more Graduate Registration Officers, administers departmental graduate activities. The Graduate Registration Officer advises and assists individual students in all aspects of their graduate work.

DEGREES

Graduate students may pursue work leading to any of the following degrees:
Doctor of Philosophy, Ph.D.
Doctor of Science, Sc.D.
Engineer Degrees (see page 64)
Master of Science, S.M.

Master in Architecture, M.Arch.
Master in City Planning, M.C.P.

FIELDS OF STUDY

The major fields for graduate study are listed below. Each graduate program is described by the department concerned in its statement on graduate education, given later in this Catalogue.

School of Architecture and Planning

Department of Architecture
ARCHITECTURE, Course IV-A

Department of City and Regional Planning
CITY AND REGIONAL PLANNING, Course IV-B

School of Engineering

Department of Aeronautics and Astronautics
AERONAUTICS AND ASTRONAUTICS, Course XVI
Aerodynamics and gas dynamics
Aeroelasticity
Aeronautical and astronautical engineering
Instrumentation
Propulsion
Space mechanics
Structures
Vehicle design and operation

Department of Chemical Engineering
CHEMICAL ENGINEERING, Course X
Applied chemistry
Engineering operations
Fuel engineering
Materials
CHEMICAL ENGINEERING PRACTICE, Course X-A

Department of Civil Engineering
CIVIL ENGINEERING, Course I
Data engineering
Hydromechanics and hydraulic engineering
Soil engineering
Structural engineering
Transportation engineering
SANITARY ENGINEERING, Course XI
BUILDING ENGINEERING AND CONSTRUCTION, Course XVII
Construction management
Materials of construction

Department of Electrical Engineering
ELECTRICAL ENGINEERING, Course VI
Communication
Computation
Control
Electrical science and engineering
Electronics
Energy processing
Molecular engineering

Department of Mechanical Engineering
MECHANICAL ENGINEERING, Course II
Applied mechanics
Design and controls
Energy conversion
Fluid mechanics
Heat engineering
Magnetohydrodynamics
Materials
Power and propulsion
Textile technology
Thermodynamics

Department of Metallurgy
METALLURGY, Course III
Ceramics
Materials engineering
Metallurgy
Mineral engineering

Department of Naval Architecture and Marine Engineering
NAVAL ARCHITECTURE AND MARINE ENGINEERING, Course XIII
Marine engineering
Naval architecture
NAVAL CONSTRUCTION AND ENGINEERING (U.S.N. and U.S.C.G.), Course XIII-A
SHIPPING AND SHIPBUILDING MANAGEMENT, Course XIII-B

Department of Nuclear Engineering
NUCLEAR ENGINEERING, Course XXII
Fission technology
Thermonuclear processes

School of Humanities and Social Science

Department of Economics and Social Science
ECONOMICS AND SOCIAL SCIENCE, Course XIV
Economics and engineering (or science)
Industrial economics
Industrial relations
Political science

Department of Modern Languages
Linguistics

School of Industrial Management

INDUSTRIAL MANAGEMENT, Course XV

School of Science

Department of Biology
BIOLOGY, Course VII
Analytical biology
Biochemistry
Biophysics
Microbiology
Physiology

Department of Chemistry
CHEMISTRY, Course V
Analytical chemistry
Inorganic and nuclear chemistry
Organic chemistry
Physical chemistry

Department of Geology and Geophysics
GEOLOGY AND GEOPHYSICS, Course XII
Geochemistry
Geology (classical geology, theoretical geology)
Geophysics
Oceanography

Department of Mathematics
MATHEMATICS, Course XVIII

Department of Meteorology
METEOROLOGY, Course XIX
Oceanography

Department of Nutrition, Food Science and Technology
NUTRITION, FOOD SCIENCE AND TECHNOLOGY, Course XX
Animal nutrition
Clinical nutrition
Flavor chemistry

Food bacteriology
Food engineering
Food processing
Food toxicology
Human nutrition
Nutritional biochemistry
Public health nutrition

BIOCHEMICAL ENGINEERING, Course XX-B

Department of Physics

PHYSICS, Course VIII

Each graduate student is enrolled in one Course. His program is not limited, however, to subjects offered in a single department. Subjects and research programs may be chosen from several departments, with the aid and counsel of the staff, as long as the over-all program is integrated and well balanced with respect to a major field of study. Occasionally an individual student's major field of interest overlaps portions of fields in several departments; in this case the Dean of the Graduate School may appoint an interdepartmental committee to be responsible for the degree program.

In addition to specialized professional competence, graduate students are expected to have a background in the humanities and social sciences. The faculty believes that those who receive advanced degrees should have the breadth of interests and understanding which tend to promote qualities of leadership and an awareness of moral responsibility, along with specialized competence. To further this objective, graduate students may take electives in any of the ten fields of study offered by the School of Humanities and Social Science.

REGISTRATION

Graduate students receive registration material in advance of each term. This material should be filled out and returned to the Registrar's Office before the beginning of the term, in accordance with instructions provided. A student entering the Graduate School from another college usually will not be able to indicate specific subjects for which he will register, but he should complete as much as possible of the registration material for prompt return to the Registrar, leaving the final choice of subjects to be determined in consultation with his Registration Officer before or on Registration Day.

ACADEMIC STANDARDS

Continuing registration of graduate students from term to term is contingent upon satisfactory academic performance. At the end of each term the Committee on Graduate School Policy reviews the performance of all graduate students whose grades during that term average less than midway between C and B. In addition, departmental graduate committees may at any time recommend to the Committee on Graduate School Policy that a student be refused further registration or that he be allowed to register only for a less advanced degree.

Admission to the Graduate School

The term Regular Graduate Student designates a holder of a baccalaureate degree who, subsequent to approval of his application for admission, is in residence at the Institute and registered for a program of advanced study and research leading to any of the post-baccalaureate degrees offered by M.I.T. A Regular Graduate Student may or may not concurrently hold an academic staff appointment such as research assistant, teaching assistant, instructor, or, in some cases, assistant professor. A student registered in a program of study leading to the simultaneous award of the Bachelor's and Master's or the Bachelor's and Engineer degrees is considered for admission as a Regular Graduate Student in competition with other applicants during his fourth undergraduate year.

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 standing acceptable to the Director of Admissions of the Institute. His academic record and other credentials must indicate ability to accomplish satisfactorily an approved program of study and research.

Applicants are judged on the basis of their prior performance and professional promise. These are evidenced by academic records, letters of evaluation from individuals familiar with the applicants' capabilities, and any other pertinent data furnished by the applicants. Since admission is not dependent solely on academic records, it is not possible to specify minimum criteria. While previous high academic achievement does not guarantee admission, such achievement, or other unusually persuasive evidence of professional promise, is expected.

Only students who have shown promise of performing truly creative work are encouraged to study for the Doctor's degree. Students entering on graduate work who do not have records that show strong evidence of this ability are usually advised to qualify first for the Master's degree.

UNDERGRADUATE PREPARATION FOR ADVANCED DEGREES

In line with the Institute's conception of a broad undergraduate curriculum polarized around mathematics and science, the departments have tended to establish the following entrance requirements for graduate study:

Mathematics. Most departments require preparation substantially equivalent to the Institute's first- and second-year mathematics: CALCULUS (18.01, 18.02, and 18.03) and statistics and DIFFERENTIAL EQUATIONS (18.04). Some require only one year, and some prefer probability and statistics.

Natural Science. Most departments require preparation substantially equivalent to the Institute's first- and second-year physics: MECHANICS (8.01); MECHANICS: HEAT AND KINETIC THEORY (8.02); ELECTRICITY AND MAGNETISM (8.03); and OPTICS AND ATOMIC PHYSICS (8.04); and the Institute's first-year chemistry: GENERAL CHEMISTRY (5.01, 5.02). Some departments require only one year of physics, and a few only one year of college-level natural science.

Humanities and Social Science. Following M.I.T.'s belief that professional education requires breadth as well as depth, all M.I.T. departments require at least six semester subjects in the humanities or social sciences equivalent in scope to those included in the undergraduate humanities curricula of the Institute. Deficiencies may be satisfied by completing appropriate subjects from fourth-year or graduate electives in the humanities and social sciences.

Professional subjects. Requirements of individual departments are given in each department's statement on graduate education.

Deficiencies in Preparation

Students with minor deficiencies in preparation may be admitted to the Graduate School; however, deficiencies in prerequisite general or professional subjects must be removed before the student may proceed with graduate work dependent on them.

If an applicant lacks so many undergraduate requirements that his work for the advanced degree is likely to be unduly protracted, he may be advised to postpone his application until his deficiencies have been reduced.

In an exceptional individual case, the Committee on Graduate School Policy will entertain a departmental proposal for modifying admission requirements and can modify any of the above requirements.

APPLICATION FOR ADMISSION TO THE GRADUATE SCHOOL

To be considered for admission to the Graduate School, an applicant must submit a completed application form, which may be obtained from the Director of Admissions, Massachusetts Institute of Technology, Cambridge 39, and should be returned to him.

Applicants for admission to the Graduate School should in general plan to enter in September, which is the beginning of the academic year. Applications for such admission, including all credentials, should be submitted by February 15. Acceptance of later applications is possible only if vacancies remain in the department specified by the applicant. When circumstances warrant, admission may be approved for entry in February or June at the beginning of the corresponding spring or summer terms.

An applicant who during his final year of work toward a Bachelor's degree files a request for admission as a graduate student may be accepted contingent upon his subsequently providing evidence that he has been awarded said baccalaureate degree.

Notification about admission is sent as soon as action is taken.

Correspondence concerning admission should be addressed to the Director of Admissions. Inquiries about preparation or subject content should be addressed to the chairman of the appropriate departmental Committee on Graduate Students. These names are listed at the beginning of this section.

ADMISSION AS A PROVISIONAL GRADUATE STUDENT

Admission as a Provisional Graduate Student may be granted to an applicant who, although unable to meet all of the above requirements for acceptance as a graduate student, is judged by a department Committee on Graduate Students to be able to pursue graduate studies successfully. Provisional graduate student status will be changed to that of Regular Graduate Student upon demonstration of such ability.

ADMISSION AS A SPECIAL GRADUATE STUDENT

A qualified applicant who wishes to enroll for graduate subjects with a clearly defined objective, but not as an applicant for a degree, may be admitted term-by-term as a Special Grad-

uate Student. He will be enrolled in the department which has approved his admission. Applications are received by the Director of Admissions, and the application and program of study must be approved by the department(s) principally concerned and by the Dean of the Graduate School.

A Special Graduate Student who is subsequently admitted as a Regular Graduate Student may offer subjects which he has completed in partial fulfilment of requirements for an advanced degree, whether or not he was a member of the M.I.T. academic staff or the Division of Sponsored Research staff at the time the work was done. His Major department will determine to what extent such subjects are acceptable and whether he will receive residence credit for them.

ADMISSION OF FOREIGN STUDENTS

Applications from foreign students for admission to the Graduate School may be considered as early as March 1 preceding the fall term for which the application is effective, and some notices about admission may be mailed shortly after that date. There is, therefore, some advantage in completing applications before March 1, though applications completed between March 1 and May 1 will receive careful consideration. Applications for a fall term which are received later than the preceding May 1 will be given consideration only under exceptional circumstances.

A few admissions to the Graduate School may be possible for the second term, beginning in February. An application for that term for which no vacancy is available will be held and considered for the following fall term.

Action on admission will not be taken until complete application material has been received by the Director of Admissions. Applications accompanied by incomplete credentials cannot be considered.

Foreign students who wish to enter the Institute for undergraduate study should refer to Section 2 of this Catalogue.

Further information about the admission of foreign students is available from the Office of the Adviser to Foreign Students, Massachusetts Institute of Technology, Cambridge 39.

GRADUATE RECORD EXAMINATIONS

All applicants are strongly urged to submit results of the Aptitude and Advanced Tests of the Graduate Record Examinations. Normally applicants will be expected to rank not lower than the median in verbal and quantitative tests and in such special tests as are appropriate.

Information as to time and location at which these tests are given can be obtained by writing to Graduate Record Examinations, Educational Testing Service, 20 Nassau Street, Princeton, New Jersey. Inquiries from students in western states should be addressed to 4640 Hollywood Boulevard, Los Angeles 27, California.

Cooperative Arrangement with Harvard University

A graduate student who is engaged full time in study or in a combination of study and academic staff duties equivalent to full time may, by permission, enroll for advanced study (exclusive of research) at Harvard University or Radcliffe College without paying additional tuition, provided that this exchange enrollment does not exceed one-half of his total registration for the term. Included in the above category are Fellows and full-time Special Graduate Students who are carried on the rolls of the Graduate School at M.I.T.

Procedure for M.I.T. Students

A student who wishes to enroll at Harvard must present to the Dean of the Graduate School at M.I.T. a written request from his Registration Officer, specifying the name and number of the Harvard subject(s) desired and whether for credit or for auditing without formal grade. The Dean's office will issue forms which the student must present first to the instructor in the subject he has chosen and then to the dean of the appropriate graduate school at Harvard. *Registration must be completed within two weeks* of the Registration Day specified by Harvard University for each term.

Requests should be confined to subjects which are not offered at M.I.T.; if there is duplication of a requested subject in the two schools, acceptable reasons for the request must be presented. Students will not be allowed to attend classes which are so crowded that additional registration puts an undue load on the instructors.

Procedure for Harvard Students

A student enrolled in a graduate school at Harvard who desires to register at M.I.T. must obtain on appropriate forms the endorsement

of the dean of his school at Harvard and the written consent of the instructor in charge of each M.I.T. subject he plans to take. This endorsed request must then be presented for approval at the office of the Dean of the Graduate School at M.I.T., Room 3-136. Upon its approval, the student will receive a letter of authorization which he must present at the Office of the Registrar, Room 7-142, in order to obtain registration material.

Such requests on behalf of Harvard students will not be approved after the end of the second week of a term at M.I.T.

Military Service

The Office of the Graduate School assists enrolled and prospective (admitted) graduate students in their representations to Selective Service Boards and/or the various military services relative to classification, deferment, or delay. Every such student, whether or not he anticipates a junior staff appointment as a teaching assistant, research assistant, or instructor, is invited to seek the School's advice and assistance in this matter.

Each prospective graduate student must see that his Selective Service Board is supplied with certification both of his class standing during his last undergraduate year and of his admission to the Graduate School. The official statement of his class standing must be supplied by the institution from which he received his baccalaureate degree. It is the student's responsibility to see that his undergraduate school sends this information directly to his draft board (on S.S.S. Form 109) within 30 days of his graduation. Since the student himself is also entitled to this information, he may request that a copy be sent to him at the same time. The Graduate School will send to the draft board of each admitted student, on a separate S.S.S. Form 103, an official certification of his Graduate School admission; a copy of this certification will also be sent to the prospective student.

Requirements for Degrees

Candidates for advanced degrees must satisfactorily complete an approved program of study and research, including an appropriate portion done in residence, before being recommended for a degree. The amount of time required to attain any one degree varies; candidates who lack undergraduate prerequisites for graduate work may be permitted to make up these deficiencies in the course of their graduate work, but those who do so must expect to spend a longer period of time in the Graduate School than is otherwise required for the degree. All the general requirements for the different degrees, as well as the residence requirements, are described in the following paragraphs.

Degrees are awarded by the Corporation of the Institute upon the recommendation of the faculty, based upon review and action by the Committee on Graduate School Policy and on recommendation from a candidate's departmental Committee on Graduate Students.

THE MASTER'S DEGREES

A student who has a Bachelor's degree from the Institute in the same department in which he enrolls for the Master's degree, or who has had equivalent preparation elsewhere, may attain the Master's degree in one year. Others with less direct or extensive preparation will require a longer time.

A student who completes the requirements for the Bachelor's degree at the Institute with substantial extra advanced credits in graduate subjects may, upon application, be granted a relaxation of the normal residence requirement (apart from thesis) and may be recommended for the Master's degree upon completion of the academic requirements.

A student who expects to come to M.I.T. for an advanced degree after earning an undergraduate degree elsewhere should give careful attention to undergraduate subjects prerequisite for the advanced work which he intends to undertake; these requirements are outlined by each department in following sections of this Catalogue. For advice on such subjects a student should write to the department in which he wishes to enroll.

Degree Requirements

The degrees of Master of Science, Master in Architecture, and Master in City Planning are awarded upon the satisfactory completion of an approved program of at least 96 units, of which 72 units are graduate ("A") subjects. The program must include a thesis of not less than 20 or more than 40 units.

The choice of field 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 Registration Officer. A special interdepartmental committee may be appointed by the Dean of the Graduate School to supervise a program in a field which spans two or more departments.

To be recommended for a Master's degree, a student must have, in addition to a clear record in a program of graduate study and research as defined above, a scholastic standing of a distinctly high grade.

Degrees With and Without Specification

In an approved program for a Master of Science degree, if 64 units of "A" subjects, including thesis, are in a single field of science or engineering (as determined by a departmental Committee on Graduate Students), the degree is recommended with specification in the field in which the student has thus specialized; otherwise, the degree is recommended without specification. The same high standard of academic performance is required in either case

Programs for the Simultaneous Award of the Bachelor's and Master's Degrees

Information concerning the opportunity for programs of study leading to the simultaneous award of the Bachelor's and Master's degrees is given under "Courses of Study" in Section 2 of this Catalogue.

THE ENGINEER DEGREES

The objective of a program leading to an Engineer degree is a more advanced level and a broader range of competence in engineering and science than that required for the Master's degree, but with less emphasis on creative research than that characterizing a doctoral program. In general terms, the Master's degree requires a minimum of one academic year and the Engineer degree of two academic years beyond a baccalaureate in the same field.

The following Engineer degrees are awarded: Civil Engineer (C.E.), Mechanical Engineer (Mech.E.), Metallurgical Engineer (Met.E.), Mineral Engineer (Min.E.), Electrical Engineer (E.E.), Chemical Engineer (Chem.E.), Sanitary Engineer (San.E.), Marine Mechanical Engineer (Mar.Mech.E.), Naval Architect (Nav. Arch.), Naval Engineer (Nav.E.), Engineer in Aeronautics and Astronautics (E.A.A.), Building Engineer (Bldg.E.), Materials Engineer (Mat.E.), and Nuclear Engineer (Nucl.E.).

The requirement for such a degree is the satisfactory completion of a program comprising at least 192 units of advanced study and research, including a thesis of not less than 20 nor more than 50 units, approved by the appropriate department of the School of Engineering. A department may accept a Master's thesis of superior quality for the Engineer degree.

A graduate of the Institute who enrolls for an Engineer degree in the same department in which he received his Bachelor's degree, or others with equivalent preparation, may complete the requirements for that degree in four academic terms; a student with less direct or extensive preparation will require a longer time.

THE DOCTORATES

M.I.T. offers the degree of Doctor of Philosophy in fields of natural or social science, engineering, city and regional planning, and industrial management; and the degree of Doctor of Science in fields of science or engineering. These degrees certify to performance of original research of high grade and to creditable completion of an approved program of advanced study, principally at the Institute.

The four basic requirements for a doctorate are:

1. Completion of a Major program of advanced study, concluding with a general examination.
2. Completion of a Minor program of study in an area distinct from that of the Major field.
3. Demonstration of proficiency in reading the technical literature of the Major field in modern foreign languages.
4. Completion and oral defense of a thesis on original research.

Experience has strongly indicated that the purposes of doctoral work are effectively served only by full-time effort in formal study or by a combination of formal study and relevant work as an academic staff appointee.

The Major Requirement

The Major program of advanced study and research may be selected in any field of science or engineering approved by the department in which the student is enrolled. The thesis is in this same field. The program of the Major often comprises subject areas reaching into several departments. If the Major field requires substantial participation by two or more departments, an interdepartmental faculty committee may be appointed by the Dean of the Graduate School to advise with a Graduate Registration

Officer in the administration of the student's program.

Each doctoral candidate will have a general examination on his Major field at such time and in such manner as his department Committee approves. This examination consists of both oral and written parts.

The Minor Requirement

The Minor requirement for a doctoral degree comprises at least three subjects (not less than 24 units of credit) in some field other than that of the Major. All of these subjects must be more advanced in character than subjects in the prescribed undergraduate curriculum of the department in which the student majors. Subjects chosen to satisfy this requirement are selected with the primary objective of contributing broadly to the development of professional leadership rather than improving technical competence in a particular region of special interest; they are normally taken in a department other than that in which the student is registered.

The full program of subjects comprising the Minor must be specifically agreed upon before its execution is commenced and must have the approval of the student's departmental Committee. This Committee files with the Registrar a record of the anticipated Minor program as soon as it is determined. Any modification must be reported promptly to the Registrar.





THE M.I.T. GRADUATE HOUSE (*also shown on the previous page*) HAS COMFORTABLE LIVING, DINING, AND RECREATIONAL FACILITIES FOR SINGLE GRADUATE MEN.





A student may occasionally wish a Minor program of subjects which satisfy the breadth characteristics for a Minor but which, for administrative reasons, are given by the department in which his Major field is centered. Or, he may plan a Minor taken in part or entirely under the Harvard or Radcliffe exchange program. In either case, such a program — if approved by the Dean of the Graduate School and by the departmental Committee concerned — is administered through the student's Registration Officer.

A student may, with the approval of his Major department, receive credit for appropriate subjects which he has previously taken as a graduate student at the Institute or elsewhere.

An examination on the field of the Minor may be required, especially if credit for a part of the Minor requirement is granted for work done elsewhere.

The Language Requirement

Each candidate for a doctorate must demonstrate by examination to the Department of Modern Languages his ability to read in English and two other modern languages the scientific literature of his Major field. These languages must be acceptable to the department in which he is enrolled and must be languages in which there is important literature in the field of his specialization. The native tongue of a student from a non-English-speaking nation will be accepted as one of the approved languages only if there is sufficient amount of important and pertinent literature in that language. Examinations are held at intervals stated by the Department of Modern Languages.

The Thesis

The calibre and scope of the doctoral thesis are such as to require, in all but very exceptional cases, the equivalent of at least one full-time academic year of research. Many doctoral researches require a substantially longer time. Each doctoral candidate is expected to register for the appropriate number of units of thesis in all periods during which work on his research and thesis are actually in progress.

The investigation must be carried out under the supervision of an M.I.T. faculty member. Work already accomplished elsewhere which has not been under the supervision of an Institute faculty member cannot be accepted in partial fulfillment of the thesis requirement, nor can credit be granted for thesis work done in absentia, except under very special conditions and with specific prior approval by the Committee on Graduate School Policy. However, work of certain types (such as the collection of data for an investigation) may, with approval of the departmental Committee on Graduate Students, be carried out elsewhere without registration or payment of tuition.

A final oral examination on the thesis and its field will be held after the thesis has been submitted and tentatively evaluated by the examiners.

RESIDENCE REQUIREMENTS

M.I.T. degrees are "residence" degrees in the sense that a major portion of the work for which each is awarded must be done with opportunity for full-time association with the M.I.T. faculty, other graduate students, and the Institute community. In the Institute environment a student lives and works in a stimulating and scholarly atmosphere; he enjoys free and unhampered discussion with his colleagues, both faculty and students, within his professional field and over a broad range of other subjects. This environment includes easy access to libraries and reference sources, to the educational opportunities offered by other disciplines, and also to recreational, cultural, religious, and athletic opportunities of this community. Experienced together, these offer the challenge and inspiration of being a working member of a team mutually striving for professional growth and advancement of knowledge.

Residence requirements are specified, not in terms of actual elapsed time, but in terms of the amount of registration during which residence benefits may be acquired.

Credit is rarely granted for thesis work done in absentia, and only on specific advance approval by the Committee on Graduate School Policy. All thesis work must be done under the supervision of a member of the Institute's academic staff.

For all the Master's degrees the minimum residence requirement is one full academic term.

For the Engineer degrees, the equivalent of two terms of full-time graduate work must be completed with residence credit.

For doctorates, the equivalent of at least two years of full-time graduate work must ordinarily be completed with residence credit, unless advanced work completed elsewhere is accepted

as equivalent by the student's Major department. In no case may the required amount of work in residence be less than the equivalent of three full-time academic terms, including research for the thesis and writing of the thesis.

Financial Assistance to Graduate Students

Financial support from M.I.T. is available to graduate students in several forms — fellowships; scholarships; junior staff appointments as instructors, teaching assistants, or research assistants; or loans from the Technology Loan Fund (see Appendix A).

In a typical recent year about 425 graduate students held fellowships and scholarships; over 300 held teaching appointments, and over 650 held research appointments.

A *fellowship* is an award of a cash stipend, with or without a credit against tuition fees, to aid the recipient in his pursuit of advanced study and research. This award, based on academic performance and promise of professional competence, recognizes the recipient as having demonstrated the promise of unusual attainments. The recipient is designated as a Fellow for the period specified in his award. He pays full tuition and has full student status, and no services are required of him in connection with the fellowship.

A *scholarship* is an award of financial credit toward tuition fees, made to a graduate student of academic promise, to aid and encourage his graduate study toward an advanced degree. When awarded to holders of academic appointments, such tuition grants are designated as Staff Scholarships.

A *junior staff appointment* provides a modest salary for the performance of staff duties in teaching or research. Such staff appointments may involve either part-time duties combined with a nearly full-time program of study, or nominally full-time duties with a nearly half-time program of study. The educational value of work as either a teaching or a research appointee is widely recognized among experienced graduate students. Indeed, such appointments are sought by most students for educational reasons at some time during their graduate programs. While the educational value of the research appointment is fairly evident, that of the teaching appointment may be less obvious; only he who has taught realizes that teaching is often the best way to learn.

A teaching appointment is normally accompanied by a staff tuition scholarship. A research appointee usually pays his own tuition, but he often has a compensating opportunity for thesis research.

Many members of the staff of the Division of Sponsored Research (D.S.R.) study graduate subjects as Special Graduate Students. However, a D.S.R. appointee who desires to work for an advanced degree must meet the residence requirement by becoming a Regular Graduate Student at some time during his degree program.

FELLOWSHIP AND SCHOLARSHIP AWARDS

Fellowships and scholarships are awarded by the Committee on Graduate School Policy only to graduate students who are not also staff members. Award of Staff Scholarships is made by the appropriate academic dean upon the recommendation of department heads.

Only regular full-time graduate students carrying substantially a full academic load are eligible for scholarship aid through the Committee on Graduate School Policy, and requests based on registration of at least 45 units per term will therefore have precedence over others. Students who receive government aid in consideration of military service are eligible on the same basis as all other graduate students. Under unusual circumstances, recipients of other than M.I.T. fellowships may also be considered for tuition awards. Provisional Graduate Students of unusual attainments and newly admitted graduate students who present credentials of outstanding excellence may be considered for financial aid. Financial need, while not a controlling factor, is taken into consideration in making awards.

Continuation of financial aid for more than one term is conditional upon maintaining academic standards necessary to continuing graduate student status. An academic record which averages below midway between B and C will usually be cause for cancellation of an unused portion of an award, unless mitigating circumstances are presented and found acceptable.

Every recipient of financial aid is expected to complete the period of study for which an award is made. If he discontinues his work before the end of this period he is regarded as under moral obligation to refund to the Bursar all portions of the award which have been paid to him or on his behalf, unless a waiver is granted by the Committee on Graduate School Policy.

Applications

An application for a fellowship or scholarship must be filed on the form "Application for Fellowship and Scholarship Aid," obtainable from the Admissions Office, and should be submitted to the chairman of the appropriate department Committee on Graduate Students.

Applications for scholarships or fellowships for the regular academic year, beginning with a fall term, must be filed by the previous February 15. Final action on applications will be taken by the Committee on Graduate School Policy before April 1; notices of award will be mailed for delivery about April 1, and awards not accepted by April 15 will be canceled.

Applications from new students who are at the same time applying for admission to the Graduate School must be accompanied by the full credentials required with the admission application. Only applicants with very high credentials may expect favorable consideration of scholarship applications before they have completed at least one term of residence as graduate students. Recently twenty to thirty Whitney Fellowship awards have been granted annually to new students with outstanding qualifications.

Applications received at dates other than February 15 will be considered from time to time if funds are available.

Inquiries concerning financial aid should be addressed to the chairman of the appropriate department Committee on Graduate Students.

JUNIOR STAFF APPOINTMENTS

Academic staff appointments as teaching and research assistants are made upon recommendation by the head of a department to his academic dean. Applications for such appointments should be made to the head of the department concerned; such applications from new students will be considered only after an Application for Admission to the Graduate School has been recorded by the Admissions Office.

RELATIONSHIP OF THE D.S.R. STAFF TO THE GRADUATE SCHOOL

In view of their full-time responsibilities on assigned research and corresponding nonacademic salary scales, staff members of the Division of Sponsored Research do not enjoy full academic privileges but may, under conditions outlined below, be granted the status of Special or Limited Graduate Student.

Any D.S.R. appointee may, by written permission from the Director of the Division (or his designate), apply for enrollment as a student in one subject only per term (but not thesis), either as auditor or for academic credit; he will be accepted for such enrollment if, in the opinion of the instructor in the subject, he is qualified to undertake it and if section size permits. For this type of enrollment he 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 and will be recorded as a Special Student. (For details, see "Fees, Deposits, and Payments" in Section 1 of this Catalogue.)

No graduate student may present as thesis any material based in whole or in part upon work done while holding a D.S.R. appointment or receiving the D.S.R. rate of compensation.

A D.S.R. appointee who at some previous time has held Regular Graduate Student status may, upon joint recommendation of a department Committee and the D.S.R. to the Dean of the Graduate School, be permitted to enjoy the status of Limited Graduate Student for the following purposes:

1. General Doctor's or comprehensive Engineer degree examinations;
2. Language examinations prescribed for advanced degrees;
3. Thesis presentation with or without thesis examination, and either with or without simultaneous enrollment on a degree list;
4. Enrollment on a degree list together with one subject.

Not more than one of the preceding four aspects will be permitted in any single term, nor will the privilege of taking one subject apply to terms in which permission is given for registration under aspects 1, 2, or 3 above. Furthermore, no request for enrollment on a degree list will be entertained (except under 4) until all degree requirements other than thesis presentation have been satisfactorily completed. D.S.R. appointees pay the fees or tuition as prescribed for Regular Students, not those applying to students holding academic staff appointments.

By approval of a Graduate Registration Officer, credits recorded for subjects completed as a Special Student may be accepted in partial fulfillment of advanced-degree requirements of a graduate student of Regular or Limited status.



ADVANCED STUDY — IN THIS CASE USUALLY FOR DOCTORS WHO WISH TO SUPPLEMENT THEIR MEDICAL WORK WITH BIOLOGICAL SCIENCE — IS WELL ESTABLISHED IN THE DEPARTMENT OF BIOLOGY.











SCHOOL FOR ADVANCED STUDY 4.

Scholars who wish to continue the kind of scholarly research initiated in their graduate years sometimes elect to pursue their studies on a postdoctoral level. While such students may be registered with individual departments, this opportunity is normally available under M.I.T.'s School for Advanced Study.

In addition to its Director and the Institute Professors, the School for Advanced Study comprises a group of scholars known as Fellows of the School for Advanced Study. To be considered for appointment as Fellow, a scholar must have a Doctor's degree, or its equivalent, and be resident at the Institute for the purpose of engaging in scholarly work on a postdoctoral level for a limited period, usually one or two academic years, in some field covered by the Institute's program. Such a scholar ordinarily works under the supervision or sponsorship of a member of the faculty. With the approval of the head of his department, the faculty member may nominate the scholar for appointment as Fellow for a limited period, usually one academic year. The nomination must be approved by an Advisory Board for the School and by the Executive Committee of the Corporation. A Fellow of the School for Advanced Study pays no tuition and receives no stipend from the Institute for this appointment. A Fellow may receive financial support from outside sources, or from funds administered by the Institute which may properly be used for the support of scholarly research at the postdoctoral level. For example, a Fellow may be the recipient of a postdoctoral fellowship or he may have an appointment as a member of the research staff.

From time to time the School may also have attached to it certain scholars of international reputation who have been invited to the Institute for the purpose of furthering the objectives of the Institute's educational and research programs.

INSTITUTE PROFESSORS

MARTIN JULIAN BUERGER, PH.D.
WILLIAM REDE HAWTHORNE, SC.D. (*Visiting*)
ROMAN JAKOBSON, PH.D.
EDWIN HERBERT LAND, LL.D., SC.D. (*Visiting*)
FRANCIS OTTO SCHMITT, PH.D., SC.D.
JOHN CLARKE SLATER, PH.D., SC.D.
CYRIL STANLEY SMITH, SC.D.

INSTITUTE PROFESSORS, EMERITI

CARL RICHARD SODERBERG, TEKN.D., D.ENG.
NORBERT WIENER, PH.D, SC.D.

SLOAN FOREIGN POSTDOCTORAL FELLOWS

JAYANTA BASU, PH.D.
G. ANTHONY JAMESON, PH.D.
YVES GUY JULLIEN, D.SC.
H. J. E. LOEWENTHAL, PH.D.
SAROJ KUMAR MAJUMDAR, PH.D.
STEPHEN MOORBATH, PH.D.
MANFREDI NICOLETTI, D.ARCH.
ARISTIDES ROJAS, M.D.
PETER TRAFFORD SPEAKMAN, PH.D.
WOJCIECH ADAM SZCZEPINSKI, D.SC.
AWADAGIN WILLIAMS, PH.D.

MARTIN JULIAN BUERGER, PH.D.
Director of the School for Advanced Study



SCHOOL OF ARCHITECTURE AND PLANNING 5.

A statement by the Dean of the School of Architecture and Planning.

As the first institution to organize and develop formal architectural education in the United States, M.I.T. has steadily held to the belief that the basic prerequisites for the study of architecture are sympathy for human institutions, esthetic perception, and the ability to understand engineering methods. These same precepts have governed the policy of M.I.T.'s Department of City and Regional Planning — the second in the United States. Our special environment gives our students great opportunities to add specific knowledge in the fields of structures and techniques. But we are alert to the fact that the spirit of man demands more than mere function or stability in a building; a student must become sensitive to visual and esthetic demands, and he must learn that the whole of architecture is greater than its parts. The planning student must go beyond the mere use of tools and techniques to a lively interest in the problems of the society in which he works.

Our School does not aim to produce a certain sort of professional man in quantity but rather to make it possible for each student to become an architect

or city planner of individual quality. This philosophy of education has been carried out mainly by creating the kind of environment where different minds and talents may find stimulus, motivation, and a sense of direction.

Although the School does not underestimate the value of learning specific skills, we feel that to stimulate interest in ideas is far more important. Hence we try to give all our students the esthetic experience of the visual arts and at the same time introduce them to the methods and attitudes of engineering. We feel that particular stress should be laid on the importance of knowing the physical laws with which an architect must deal in performing his tasks, and we try to show the importance of working in the team, not only with engineers but with others in the many fields of action in which architects and planners are called upon to function. It is in the approach to and understanding of problems rather than in their specific solution that education makes its most effective contribution.

The education of the architect and planner covers a great range of interests. In this School we encourage students to develop both common sense and passion and within those two virtues to learn to search for facts, to understand techniques, to coordinate results, and finally to synthesize them in clear and creative expressions. We hope thereby to give them the courage to be dissenters when necessary without relinquishing poise and restraint, so that inventiveness may at all times be motivated by logic and by the satisfaction of visual order rather than by the desire to be different.

PIETRO BELLUSCHI

Department of Architecture

LAWRENCE BERNHART ANDERSON, M.ARCH.
Professor of Architecture; Head of the Department
ALBERT BUSH-BROWN, PH.D.
Associate Professor of Architectural History; Executive Officer
HERBERT LYNES BECKWITH, M.ARCH.
Professor of Architecture
GYORGY KEPES, M.A.
Professor of Visual Design
PIETRO BELLUSCHI, DOTT.ING., LL.D., SC.D.
Professor of Architecture; Dean of the School of Architecture and Planning
EDUARDO FERNANDO CATALANO, M.ARCH.
Professor of Architecture
HALLDOR GUNNLØGSSON
Bemis Professor of Architecture (Visiting)
ERNEST NAPOLEON GELOTTE, S.B.
Associate Professor of Construction
WILLIAM HOSKINS BROWN, M.ARCH.
Associate Professor of Architecture
RICHARD FILIPOWSKI, B.A.
Associate Professor of Visual Design
ROBERT BRADFORD NEWMAN, M.A., M.ARCH.
Associate Professor of Architecture
ROBERT ORMEROD PREUSSER
Associate Professor of Visual Design
MARVIN EDWARD GOODY, M.ARCH., M.C.P.
Assistant Professor of Architecture
IMRE HALASZ, DIPL.ARCH.
Assistant Professor of Architecture
JOHN RANDOLPH MYER, B.ARCH.
Assistant Professor of Architecture
HENRY ARMAND MILLON, A.M., M.ARCH.
Assistant Professor of Architectural History
MAURICE KEITH SMITH, B.ARCH.
Assistant Professor of Architecture

Lecturers

JOSEPH HUDNUT, D.F.A.
CARL KOCH, M.ARCH.
PAUL WEIDLINGER, M.S.

Instructor

JOSEPH JAMES SCHIFFER

Technical Instructor

NISHAN BICHAJIAN

Professors Emeriti

HENRY LATIMER SEAVER, A.M.
Professor of History, Emeritus
WALTER ROY MacCORNACK, SC.D.
Professor of Architecture, Emeritus

Architecture is an art; its finest achievements are creations of artistic imagination. Yet technology is the means to architecture, and architecture satisfies wants related to many areas of human affairs. Thus it has become the American preference that schools of architecture be lodged in universities, where the art of design can be fortified by scholarship and research in humanities, science, and engineering.

Contained within an institution especially alert to technology's potential for improving human life, M.I.T.'s Department of Architecture is dedicated to the search for a physical environment which expresses our culture, which encompasses the scientific outlook, and which uses modern industrial methods and materials while giving full satisfaction to our hunger for aesthetic fulfillment.

THE UNDERGRADUATE CURRICULUM

Architecture (Course IV-A)

In conformity with other schools accredited by the architectural profession, M.I.T. offers a five-year undergraduate professional Course leading to the degree of Bachelor in Architecture. This curriculum combines a program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) with a program of departmental and basic engineering studies designed to provide a generalized but thorough introduction to architecture (the Departmental Program). Supplemented by practical experience, this five-year program provides preparation for independent practice.

Candidates for the Bachelor's degree include students who enter directly from secondary schools and some who come with advanced standing from programs of liberal education at other institutions.

The Department's faculty and its teaching program combine a strong core of achievement in architectural design with high-level programs in visual design, art history and criticism, structures, and acoustics. Work in planning is provided by the sister Department of City and Regional Planning, and several engineering departments contribute subjects of professional concern to the architect.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities

and social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

The curriculum requirements are as follows:

	GENERAL INSTITUTE REQUIREMENTS			Total units
2.721	[1]GRAPHICAL CONCEPTS	0	4	2
2.722	DESCRIPTIVE GEOMETRY	0	4	2
8.01	[1]PHYSICS	4	1	6
8.02	[1]PHYSICS	4	1	6
8.03	[2]PHYSICS			
or		4	1	5
8.031	[2]PHYSICS			
8.04	[2]PHYSICS			
or		4	1	5
8.041	[2]PHYSICS			
18.01	[1]CALCULUS	3	0	6
18.02	[1]CALCULUS	3	0	6
21.01	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.02	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.03	MODERN WESTERN IDEAS AND VALUES	3	0	5
21.04	MODERN WESTERN IDEAS AND VALUES	3	0	5
	[1]*Freshman electives*		22	
	[3]*Humanities and social science electives*		32	
				158

A thesis or project is part of the General Institute Requirements. The required units of THESIS are given under the Departmental Program below.

	DEPARTMENTAL PROGRAM			
	Required subjects			
	Visual Design			
4.02	FORM AND DESIGN	0	9	11
4.04	LIGHT AND COLOR	0	9	11
	Architectural Design			
4.11	ARCHITECTURAL DESIGN	0	9	11
4.131	ARCHITECTURAL DESIGN	0	9	11
4.132	ARCHITECTURAL DESIGN	0	9	11
4.141	ARCHITECTURAL DESIGN	0	12	8
4.142	ARCHITECTURAL DESIGN	0	12	8
4.151	ARCHITECTURAL DESIGN	0	12	8
4.153	THESIS RESEARCH	0	6	0
	Structures			
4.30	ARCHITECTURAL FORM AND STRUCTURE	3	0	6
2.01	MECHANICS OF SOLIDS I	3	0	5
4.31	STRUCTURAL ANALYSIS	2	6	0
4.32	STRUCTURAL ANALYSIS	2	6	0
	Technology			
2.661	HEATING AND VENTILATION	2	0	4
2.662	HEATING AND VENTILATION	2	0	4
17.73	MATERIALS — WOOD, PLASTICS, FABRICS	3	0	3
17.74	MATERIALS — MASONRY AND METALS	3	2	4
	Planning			
4.52	CITY PLANNING PRINCIPLES	2	0	4
	History			
4.65	INTRODUCTION TO ART AND ARCHITECTURE	3	0	5
4.66	MODERN ART AND ARCHITECTURE	3	0	5
	THESIS		18	
				266
	Elective Subjects *(see below)*			**51**
	Total units required for the B.Arch. degree			**475**

[1] Subjects of the first-year program. See pages 38–39.
[2] 8.03 and 8.04 are normally taken. 8.041, if selected in place of 8.04, must be followed by 8.051 (or 8.05).
[3] See pages 39–42 for the humanities and social science program. ECONOMIC PRINCIPLES I (14.01) is required. Subjects in Field Ten (Visual Arts) may not be used in satisfaction of the humanities and social science requirements.

ELECTIVE SUBJECTS

In planning his elective program each student should consider opportunities for broad coverage in many areas as well as development in depth of an area close to his professional interest, such as structures, materials technology, acoustics, visual design, city planning, or theory and criticism. Subjects offered by other departments (including subjects in the humanities) may often be appropriate to these objectives. The following subjects offered within the School of Architecture and Planning are designed to be suitable as undergraduate electives.

4.031 VISUAL DESIGN PROBLEMS (2–6–0)
4.032 VISUAL DESIGN PROJECTS (2–6–0)
4.06 ADVANCED VISUAL DESIGN *
4.33 STRUCTURES SEMINAR (2–0–4)
4.34 STRUCTURES SEMINAR (2–0–4)
4.41 ARCHITECTURAL ACOUSTICS (3–0–5)
4.42 SPECIAL PROBLEMS IN ARCHITECTURAL ACOUSTICS *
4.43 INDUSTRIALIZED HOUSE (2–2–4)
4.47 SITE PLANNING (1–2–3)
4.571 URBAN LANDSCAPE (2–0–4)
4.61 ARCHITECTURE OF CITIES (3–0–5)
4.62 ARCHITECTURE IN THE CONTEMPORARY CITY (2–0–4)
4.67 THEORIES OF ARCHITECTURE *
4.68 ARCHITECTURAL CRITICISM *
4.70 PEOPLE IN THE URBAN ENVIRONMENT (2–0–4)
4.81 CITY STRUCTURE AND ECONOMIC DEVELOPMENT (2–0–4)
4.85 REAL ESTATE ECONOMICS (2–0–4)

CREDITS FOR TRANSFER STUDENTS HOLDING A PREVIOUS DEGREE

A student admitted into the Course in Architecture who holds a degree from his previous college will be considered to have completed the requirements of two years of the normal architectural curriculum, provided that he has completed the following studies to the satisfaction of the appropriate departments at the Institute.

Two years of subjects in English and history.
One year of mathematics, including differential and integral calculus.
Two years of natural science, including at least one year of physics.
One year of statics and strength of materials.
One semester of descriptive geometry.
One year of studio work in drawing and design.
Subjects acceptable as first-year electives.

Applicants may submit samples of their work in design to assist in evaluation.

* Time arranged.

GRADUATE STUDY IN ARCHITECTURE

The Department offers work leading to the degree of Master in Architecture. Like the undergraduate degree, this second professional degree is primarily designed as preparation for architectural practice, although it may also attract students who are considering teaching, writing, or research. Maturity in architectural design is an essential objective of the program. Course work to develop and evaluate individual design skill and range of professional knowledge is prerequisite to approval for independent specialized studies or thesis. The entire Department faculty is concerned with the guidance of these advanced studies.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

Undergraduate preparation in architecture usually differs from that required for the scientific degrees. The following requirements are substituted for those in Section 3 of this Catalogue:

Architecture. Bachelor in Architecture or equivalent degree with high academic standing from a professional undergraduate course in architecture at an institution of recognized standing; or S.B. or A.B. degree with high standing plus professional work in a school of architecture of recognized standing, as described below.

Evidence of satisfactory preparation in the following undergraduate subjects will be required for all graduate students in architecture:

Mathematics and Physics. Two years of college work in one or more of the fields of mathematics and the physical and natural sciences.

Humanities. At least six semester courses in English, history, economics or other subjects equivalent in scope to those included in the undergraduate humanities curricula of the Institute.

Professional Subjects in Architecture. Two full years of subjects in mechanics and structural design and one full year of subjects in other engineering aspects of building; a completed program of work in history of architecture, visual design, and architectural design equivalent to these subjects as required in the Institute's curriculum for the Bachelor in Architecture.

Deficiencies in mathematics and physics may be removed by enrolling in subjects offered by the Institute. A student whose deficiencies are of minor extent will be permitted graduate registration while taking the appropriate subjects at the Institute to remove them.

MASTER IN ARCHITECTURE

The degree of Master in Architecture is awarded upon satisfactory completion of a program with a minimum of 96 units of advanced study, subdivided as set forth in Section 3, including a minimum of two terms of architectural design, THESIS RESEARCH (4.163), and a thesis of from 20 to 30 units. Completion ordinarily involves twelve months of residence for graduates of five-year professional courses.

Department of City and Regional Planning

JOHN TASKER HOWARD, M.C.P.
Professor of City Planning; Head of the Department
FREDERICK JOHNSTONE ADAMS, B.ARCH.
Professor of City Planning
CHARLES ABRAMS, LL.B.
Professor of Land Economics (Visiting)
LLOYD RODWIN, PH.D.
Professor of Land Economics; Chairman of the Faculty Committee, Joint Center for Urban Studies of M.I.T. and Harvard
NORMAN WILLIAMS, JR., B.A., LL.B.
Professor of City Planning (Visiting)
ROLAND BRADFORD GREELEY, A.B.
Professor of Regional Planning; Director of Admissions
KEVIN ANDREW LYNCH, B.C.P.
Associate Professor of City Planning
AARON FLEISHER, SC.D.
Associate Professor of Urban and Regional Studies
JOHN FRIEDMANN, PH.D.
Associate Professor of Regional Planning
DONALD SIDNEY APPLEYARD, M.C.P.
Assistant Professor of Urban Design

The Department of City and Regional Planning focuses attention principally on the study of our large-scale physical environment and its interaction with our society. The Department's graduate curriculum aims primarily at training practitioners or staff men in the fields of city and regional planning; and it also offers special opportunities for students interested in teaching and research in these and related fields. Advanced students receive a broad picture of the entire field of planning, supplemented by work in library, workshop, and field. Electives in city planning, land economics, and similar subjects may be chosen by qualified students whose major interests are in related fields.

UNDERGRADUATE PREPARATION FOR CITY AND REGIONAL PLANNING

The Department does not offer an undergraduate degree. However, undergraduates who expect to do graduate work in the Department may, by a careful selection of elective subjects during their last two undergraduate years, reduce the time normally needed to complete the requirements for the Master's degree. Qualified students who have made full use of their elective time in Architecture (Course IV-A) may complete the requirements for the degree of Master in City Planning, except for thesis, in two academic terms. Civil Engineering (Course I) is also considered good preparation for graduate work in city planning, provided full advantage is taken of elective subjects to meet the prerequisites for graduate study in the Department. Other suitable undergraduate Courses are Economics, Politics, and Engineering (Course XIV-A), Industrial Management (Course XV), and Humanities and Engineering (Course XXI-A).

Students who plan to enter the graduate Course in City Planning should discuss their undergraduate programs with the Department's Registration Officer, preferably during their second year.

GRADUATE STUDY IN CITY AND REGIONAL PLANNING (COURSE IV-B)

The Department of City and Regional Planning offers graduate work leading to the degrees of Master in City Planning and Doctor of Philosophy in City and Regional Planning. The Course is open to students with varying backgrounds; architecture, landscape architecture, civil engineering, economics, sociology, law, and public administration all offer suitable preparation.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

Undergraduate preparation for city planning usually differs from that required for the scientific degrees. In place of the general requirements given in Section 3 of this Catalogue, the following are prerequisites for graduate study:

Mathematics and Physics. Two years of college work in one or more of the fields of mathematics and the physical and natural sciences.

Humanities. At least six semesters of work in English, history, economics (or allied subjects), and other humanities subjects equivalent in scope to those included in the undergraduate curricula of the Institute.

Deficiencies in any of the above subjects may be removed by enrolling in subjects offered by the Institute.

General. A broad, sound general education, with competence in communication through oral, written, and graphic expression and through mathematics, is essential; previous specialization in some related professional field is also desirable.

The Graduate Degrees

MASTER IN CITY PLANNING

The degree of Master in City Planning is awarded upon satisfactory completion of a program with a minimum of 96 units of advanced study, subdivided as set forth in Section 3. Two years are usually required for completion of the program. Students normally devote about half of their time to workshop problems in city and regional planning (including a thesis during their last term). The balance of the time is given to seminar and class work in such subjects as planning techniques, planning legislation and administration, housing, land economics, regional planning, urban design, and theory and research in planning. Three months of office practice is required and is usually satisfied by summer employment between the two academic years.

DOCTOR OF PHILOSOPHY IN CITY AND REGIONAL PLANNING

Advanced students planning research or teaching careers in city and regional planning or in urban studies may be accepted as candidates for the doctorate. Prerequisites are substantially the same as for the Master's degree.

Doctoral candidates must prepare for a General Examination covering four fields, of which two are designated as *primary* and require more intensive work than the other two, which are designated as *secondary*. Planning theory is required as one of the fields for all students. Other possible fields include planning techniques; transportation and utilities planning; land-use economics and planning; plan implementation; regional planning; urban design; science, technology, and planning; physical planning problems of developing areas; and social and cultural aspects of planning.

Following the Institute rules, candidates for the Ph.D. degree will be required to take a minor in a field other than city and regional planning. Possibilities include economic development, statistical theory and methods, public policy, political and economic planning, transportation engineering, and architectural design. Candidates will also be required to demonstrate their ability to read professional literature in two modern foreign languages. This requirement must be satisfied prior to the start of research on the Ph.D. thesis.

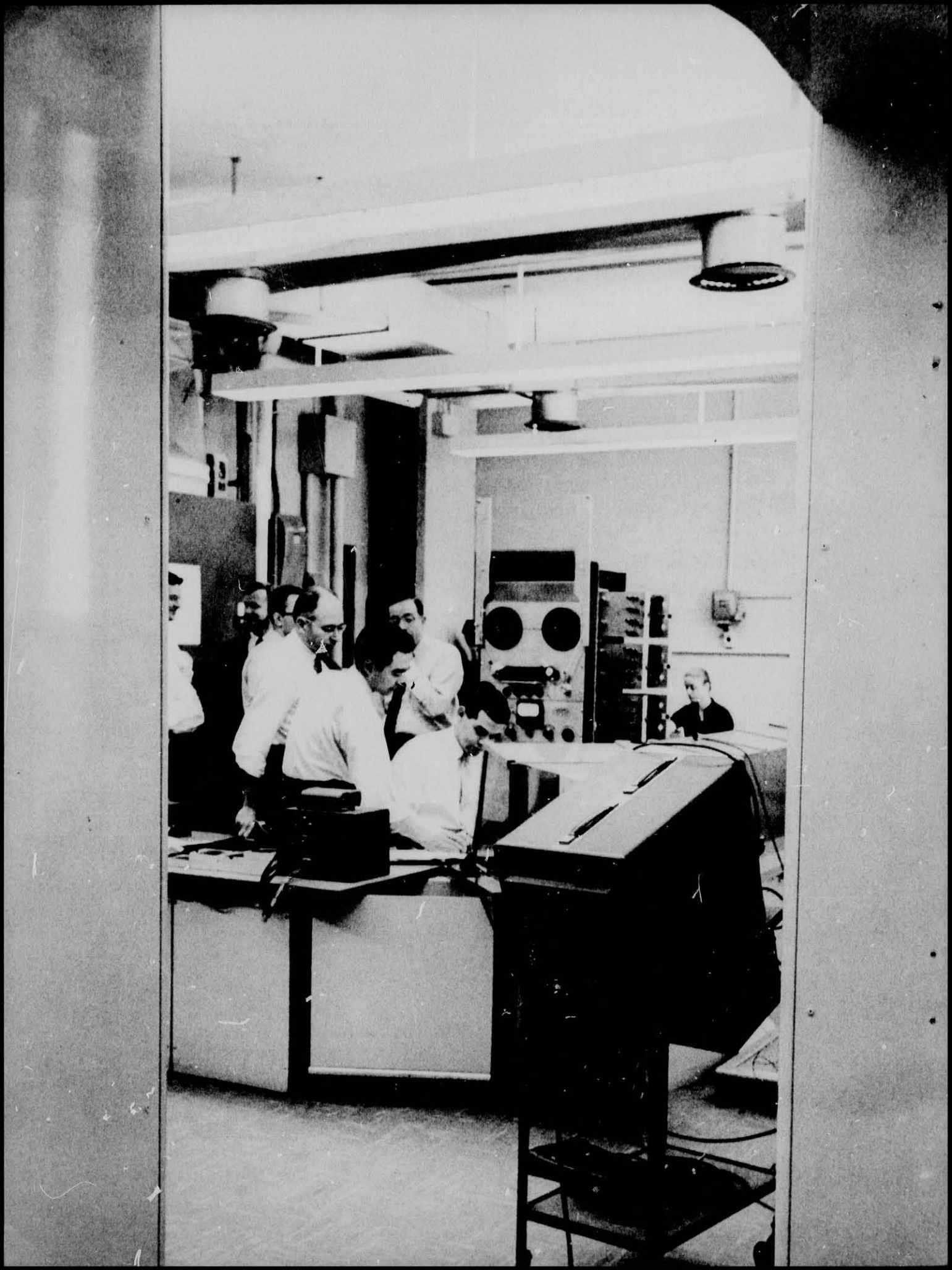
Applicants for the Ph.D. degree must receive formal permission to continue the program before beginning the second year of graduate work.

Upon completion of the course program, students will be required to take three examinations: (a) a written test covering their fields of specialization; (b) a problem of not less than two weeks' duration, followed by an oral examination on the written report; (c) an oral examination in their fields of specialization.

Upon successful completion of these examinations, students are required to prepare a written doctoral thesis evidencing the capacity to do independent research in some approved field of study. Each student is examined orally on his thesis.

No stated number of graduate subjects is required. Doctoral candidates who already hold the M.C.P. degree will require at least two terms of study in residence before beginning their theses. Other candidates may require up to six terms, depending on their preparation.

Study for the doctorate in city and regional planning may be associated with the research program of the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University.



SCHOOL OF ENGINEERING 6.

GORDON STANLEY BROWN, SC.D., D.ENG.
Dean

WILLIAM WALTHER SEIFERT, SC.D.
Assistant to the Dean

ENGINEERING COUNCIL

CHARLES STARK DRAPER, SC.D.
Head, Department of Aeronautics and Astronautics

RAYMOND LEWIS BISPLINGHOFF, SC.D.
Deputy Head, Department of Aeronautics and Astronautics

EDWIN RICHARD GILLILAND, SC.D., D.ENG.
Head, Department of Chemical Engineering

ROLF ELIASSEN, SC.D.
Acting Head, Department of Civil and Sanitary Engineering

PETER ELIAS, PH.D.
Head, Department of Electrical Engineering

HORTON GUYFORD STEVER, PH.D., SC.D.
Head, Department of Mechanical Engineering
Head, Department of Naval Architecture and Marine Engineering

JOHN CHIPMAN, PH.D., SC.D.
Head, Department of Metallurgy

MANSON BENEDICT, PH.D.
Head, Department of Nuclear Engineering

HAROLD SOMERS MICKLEY, SC.D.
School Representative on Faculty Committee on Educational Policy

EXECUTIVE OFFICERS

JOSEPH BICKNELL, S.M.
Department of Aeronautics and Astronautics

CHARLES HEAD NORRIS, SC.D.
Department of Civil and Sanitary Engineering

CARLTON EVERETT TUCKER, S.B.
Department of Electrical Engineering

JAMES HOLT, S.B.
Department of Mechanical Engineering

THOMAS BURNESS KING, PH.D.
Department of Metallurgy

JOHN HARVEY EVANS, B.ENG.
Department of Naval Architecture and Marine Engineering

SCHOOL PROFESSORS

CARL F. J. OVERHAGE, PH.D.
Professor of Engineering

JOHN BENSON WILBUR, SC.D.
Consulting Professor of Engineering

Dean Gordon S. Brown describes the role of the engineer and M.I.T.'s program of education for leadership in engineering.

It is the engineer who is bringing about the great revolution in technology. Largely by his efforts we have at last achieved the technical potential for the creation of a society free from want.

Increasingly the achievements of our engineering leaders derive more from a mature and imaginative exploitation of today's scientific knowledge than from ingenuity or tinkering, no matter how skillful these may be. Through a coupling of deep scientific skill with purposeful engineering motivation, engineers have provided, for example, a host of new machines and new materials; spectacular systems of transportation, communication, power and propulsion; and the tools for the automated mass production of consumer goods of many kinds. As engineers continue to enrich our society by conceiving, designing, building, and managing our great engineering and industrial systems, they are instigators of rapid change not only in engineering itself but in the economic, social, and cultural environment of the world.

Although engineers deal extensively with facts and scientific principles, they also must carry out their work as leaders

of men. Their ultimate stature, therefore, often finds expression in those situations where judgment and wisdom weave the elements of scientific knowledge into the whole fabric of society. Accordingly, the educational plan at M.I.T. interlaces a sequence of studies in science, engineering, and the humanities with involvement in research, in a manner that embraces all the elements of a truly liberal education.

Among M.I.T.'s 25,000 engineering alumni are many who have become independent professional consultants, college or university professors, or entrepreneurs responsible for their own businesses. The majority of them, however, are either on the staffs of industries, where they perform technical work of a highly varied and challenging character, or are members or leaders of management in industry. As the impact of engineering in world affairs accelerates, M.I.T. engineers in ever increasing numbers have the distinction of serving as advisers to government on many important issues.

The various curricula within the School of Engineering are sufficiently general so that no student is confined to a narrow specialization. In fact, specialized knowledge is now of such quantity and its application so sophisticated that it cannot be mastered in four, five, or even six years. Furthermore, the engineer and the scientist, working in concert, are setting such a pace in technological change that specialization is often outmoded several times within the span of a professional lifetime.

It is not enough merely to prepare an engineer to keep abreast of a particular contemporary technology. Accordingly, the goal of the School is to equip its students with an understanding of the basic sciences — mathematics, physics and chemistry — and of the engineering of science; and to develop in them a versatility of mind and an ability to learn anew so that, as professional engineers, they will work at the frontiers of their field and bring forth new technologies, the very nature of which may be essentially unknown during the period of their formal education.

The curriculum of the freshman year and about two-thirds of the curriculum of the sophomore year are, in effect, identical for all Courses at M.I.T. The technical and professional subjects that lead to a major field begin only in the later years. Mature professional education finds its full expression in the graduate years. The student who decides early in his program on the broad field of his major may enter a department at the beginning of the sophomore year. In most instances this student may elect, for about one-third of his sophomore studies, subjects that are a definite part of his major program. On the other hand, the student who wishes to postpone his choice of department until the end of the sophomore year need not necessarily delay his graduation beyond four years, because any sequence of elective subjects he chooses for the one-third of the sophomore year will be credited to his total degree requirements.

The basis of choice among engineering fields should lie within — rather than outside — each student's mind and personality. When assessing the question of becoming identified with a particular engineering field during a period of study, a student is wise to

choose the one which provides an immediate, potent source of motivation and inspiration rather than to attempt to foresee what his permanent area of professional activity may be. To find expression for one's gifts and to carry one's education as far as those gifts justify is the essential purpose of higher education.

The undergraduate programs of all departments of the School of Engineering are built upon a strong scientific base to give knowledge of enduring value. Each program leads to a wide range of choice of a career and serves as preparation for continued on-the-job study following graduation, or further formal graduate study in a broad spectrum of fields. A student may thus safely follow his own intuition with the conviction that his training will equip him for the unknown future, whatever the details of his professional career may be.

GORDON S. BROWN

THE UNDERGRADUATE CURRICULA IN THE SCHOOL OF ENGINEERING

The S.B. curricula in the School of Engineering consist of a common program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) and groupings of subects appropriate to particular engineering fields (the Departmental Programs). The General Institute Requirements are given below. The Departmental Programs are given by each department in the following pages.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities or social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

				Total Units
GENERAL INSTITUTE REQUIREMENTS				
5.01	[1]GENERAL CHEMISTRY	4	2	5
5.02	[1]GENERAL CHEMISTRY	4	2	5
8.01	[1]PHYSICS	4	1	6
8.02	[1]PHYSICS	4	1	6
8.03	PHYSICS			
or		4	1	5
8.031	PHYSICS			
8.04	PHYSICS			
or		4	1	5
8.041	[2]PHYSICS			
18.01	[1]CALCULUS	3	0	6
18.02	[1]CALCULUS	3	0	6
18.03	CALCULUS	3	0	6
18.04	DIFFERENTIAL EQUATIONS	3	0	6
21.01	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.02	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.03	MODERN WESTERN IDEAS AND VALUES	3	0	5
21.04	MODERN WESTERN IDEAS AND VALUES	3	0	5
	[1]*Freshman electives*		12	
	[3]*Humanities and social science electives*		32	
				176

A thesis or project of at least 9 units is required in each curriculum in the School of Engineering. Each Departmental Program states the minimum thesis units required in that curriculum.

[1] Subjects of the common first-year program. See pages 38–39.

[2] 8.041, if selected, must be followed by 8.051 (or 8.05).

[3] See pages 39–42 for the humanities and social science program.

Department of Aeronautics and Astronautics

CHARLES STARK DRAPER, SC.D.
Professor of Aeronautics and Astronautics; Head of the Department; Director of the Instrumentation Laboratory

RAYMOND LEWIS BISPLINGHOFF, D.SC.
Professor of Aeronautics and Astronautics; Deputy Head of the Department

JOSEPH BICKNELL, S.M.
Associate Professor of Aeronautics and Astronautics; Faculty Operations Officer

JEROME CLARKE HUNSAKER, SC.D., ENG.D.
Professor of Aeronautical Engineering, Emeritus

OTTO CARL KOPPEN, S.B.
Professor of Flight Vehicle Engineering

EDWARD STORY TAYLOR, S.B.
Professor of Flight Propulsion

JOHN RAYMOND MARKHAM
Professor of Aeronautical Engineering, Emeritus; Lecturer

SHATSWELL OBER, S.B.
Professor of Aeronautical Engineering, Emeritus; Lecturer

HORTON GUYFORD STEVER, PH.D., SC.D.
Professor of Aeronautics and Astronautics; Head of the Department of Mechanical Engineering; Head of the Department of Naval Architecture and Marine Engineering

WALTER WRIGLEY, SC.D.
Professor of Instrumentation and Astronautics

RENE HARCOURT MILLER, M.A.
Professor of Flight Vehicle Engineering

HOLT ASHLEY, SC.D.
Professor of Aeronautics and Astronautics

SAMUEL HERRICK, PH.D.
Jerome Clarke Hunsaker Professor of Aeronautical Engineering (Visiting)

YAO TZU LI, SC.D.
Professor of Aeronautics and Astronautics

PAUL EDWIN SANDORFF, S.B. (*Absent*)
Professor of Aeronautics and Astronautics

WALTER McKAY, S.M.
Associate Professor of Aeronautics and Astronautics

WALTER HENRY GALE, S.M.
Associate Professor of Aeronautics and Astronautics; Special Assistant

ROBERT KARL MUELLER, SC.D.
Associate Professor of Aeronautics and Astronautics

ROBERT LOUIS HALFMAN, S.M.
Associate Professor of Aeronautics and Astronautics

MORTON FINSTON, PH.D.
Associate Professor of Aeronautics and Astronautics

ERIK LEONARD MOLLÉ-CHRISTENSEN, SC.D.
Associate Professor of Aeronautics and Astronautics

LEON TRILLING, PH.D.
Associate Professor of Aeronautics and Astronautics

MARTEN TEODOR LANDAHL, DR.TECHN.
Associate Professor of Aeronautics and Astronautics

JAMES WAH MAR, SC.D.
Associate Professor of Aeronautics and Astronautics

THEODORE HSUEH-HUANG PIAN, SC.D.
Associate Professor of Aeronautics and Astronautics

HENRY PHILIP WHITAKER, S.M.
Associate Professor of Aeronautics and Astronautics

EMMETT ATLEE WITMER, SC.D.
Associate Professor of Aeronautics and Astronautics

JUDSON RICHARD BARON, SC.D.
Associate Professor of Aeronautics and Astronautics

WALLACE EARL VANDER VELDE, SC.D.
Associate Professor of Aeronautics and Astronautics

FRANK KINGSLEY BENTLEY
Assistant Professor of Aeronautics and Astronautics

ELMER EUGENE LARRABEE, S.M. (*Absent*)
Assistant Professor of Aeronautics and Astronautics

MYRON ARNOLD HOFFMAN, SC.D.
Assistant Professor of Aeronautics and Astronautics

JOHN DUGUNDJI, SC.D.
Assistant Professor of Aeronautics and Astronautics

WINSTON ROSCOE MARKEY, SC.D.
Assistant Professor of Aeronautics and Astronautics

JAMES LEE STOCKARD, S.B.
Assistant Professor of Aeronautics and Astronautics

GORDON CEDRIC OATES, PH.D.
Assistant Professor of Aeronautics and Astronautics

JACK LEO KERREBROCK, PH.D.
Assistant Professor of Aeronautics and Astronautics

SAUL SIGMOND ABARBANEL, PH.D.
Assistant Professor of Aeronautics and Astronautics

CARL RICHARD PETERSON, S.M.
Assistant Professor of Aeronautics and Astronautics

Lecturer

RICHARD HORACE BATTIN, PH.D.

Instructor

WALTER MARK HOLLISTER, S.M.

Research Associate

LEON HOMER SCHINDEL, SC.D.

Professors Emeriti

JEROME CLARKE HUNSAKER, SC.D., ENG.D.
Professor of Aeronautical Engineering, Emeritus

JOHN RAYMOND MARKHAM
Professor of Aeronautical Engineering, Emeritus; Lecturer

SHATSWELL OBER, S.B.
Professor of Aeronautical Engineering, Emeritus; Lecturer

AERONAUTICS AND ASTRONAUTICS

Aeronautics and astronautics deal with the problems of manned or unmanned vehicles that operate above the earth's surface. These include fixed-wing aircraft, helicopters, ballistic missiles, guided missiles, and space vehicles. Successful realization of systems based on such devices requires that solutions be found for the static and dynamic problems of sustentation, fluid resistance to motion, propulsion, strength and elasticity of minimum-weight structures, manual and automatic control, and measurements under difficult environmental conditions. It is the primary objective of the Department of Aeronautics and Astronautics to give a clear understanding of all these important problems and to provide students with a broad background of education in the art and science of applying sound judgment in achieving acceptable solutions for practical situations.

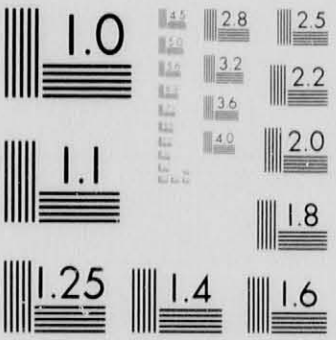
More than any other, the factor which influences the educational climate of the Department is the extensive, vigorous participation by faculty members in the activities of one or more of the several departmental research laboratories. Because all faculty members are actively interested in teaching, the aeronautical research problems of one day can and often do become the classroom examples or assignments of the next. Many undergraduate and graduate students find that part-time employment in one of the laboratories provides experience that is an invaluable supplement to formal courses. Such experience commonly suggests thesis projects. The extensive research facilities of the Department are available to its student body for thesis work or instruction, and the utilization is high for both of these purposes. Basic contributions to aeronautical science in such areas as automatic control, inertial navigation, turbojet engines, aeroelasticity, and aerodynamic heating have originated from student-faculty collaboration on thesis projects.

Many types of problems may be studied in the many facilities of the *Aerospace Research Division.* Undergraduates develop their skills and ingenuity designing and carrying out experiments in a projects laboratory, where the chief facility is space itself, along with benches and measuring and recording devices. As they progress, they make use of the more elaborate facilities of other laboratories within the Division. Many types of equipment are available for theses and other research. For structural tests, there are testing machines, instruments, and electric furnaces to investigate structural components and materials under static, dynamic, and thermal loadings. In the aircraft instruments laboratory there is extensive equipment for studying the performance of measuring and control systems both for instruction in fundamental principles and for research. Several wind tunnels are available for aerodynamic research: a 5 by 7 foot throat low-speed atmospheric pressure tunnel, a 7½ by 10 foot throat tunnel operating at pressures from ¼ to 4 atmospheres, an intermittent transonic tunnel with 22 inch slotted wall test section, an intermittent Mach 1.2 to 2 tunnel with about a 2 foot adjustable throat. Others are an 18 by 24 inch tunnel operable continuously at Mach numbers from subsonic to 7.5 at pressures up to 7 atmospheres and stagnation temperatures to 1500° R, a 5 by 5 inch Mach 5 circuit, a magnetogasdynamic facility operating at low supersonic speeds at temperatures up to 50,000°R, and several shock tubes. Auxiliary equipment is available for measuring steady and transient behavior of rigid and elastic models.

The *Instrumentation Research Division* is a large defense research organization devoted to research and development on inertial guidance and space navigation systems. Its equipment is extensive, including several digital and analog computers; it has also a test facility at Hanscom Air Force Base. Research projects are so organized that students may obtain advanced professional experience, similar to an internship in the development of real projects. Valuable sources of thesis topics are also provided. Results of current research are applied directly to graduate academic subjects and ultimately to all teaching in the Department.

Operated jointly with the Mechanical Engineering Department, the *Gas Turbine Laboratory* facilities are devoted to the study of fluid-dynamic phenomena in turbines, compressors, and combustion chambers; boundary layer flow; and the mixing of jets. The Laboratory includes an 8 by 8 inch supersonic wind tunnel, along with other experimental apparatus of all types related to flight propulsion research.

Several groups of professors work cooperatively on research projects involving study and analysis and often some use of the laboratory facilities. These groups provide excellent opportunities for student research and thesis investigations.



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THE UNDERGRADUATE CURRICULA

Aeronautics and Astronautics (Course XVI)

Undergraduate education in aeronautics and astronautics is regarded as a period of grounding in fundamentals, of acquiring habits of learning and patterns of thought. During the first two years, the undergraduate curriculum is devoted almost entirely to providing a strong preparation in the basic sciences, the engineering sciences, and mathematics. A working mastery of mathematics, chemistry, physics, thermodynamics, mechanics, material science, and electrical science is a necessary prerequisite to the subsequent study of professional subjects in aeronautics and astronautics. The professional subjects are contained largely in the third and fourth years of the undergraduate curriculum.

Each student has a wide choice in the selection of these professional subjects; he may make this choice to correspond with his own aptitude and interests, constrained only by the necessity of pursuing a well-balanced program of adequate depth. The exact program which he follows is arrived at jointly with his Faculty Counselor. Although a variety of combinations of the professional subjects may be designed, the Department suggests two general types of programs which in its judgment prepare students especially well for aeronautics and astronautics. These are termed the Engineering Program and the Engineering Science Program. The Course leads to the degree of Bachelor of Science in Aeronautics and Astronautics.

ENGINEERING PROGRAM

Unlike most engineering curricula, aeronautical and astronautical engineering has the distinguishing feature of being polarized around a flight vehicle. This polarization provides for students a continuous object and goal which is of great motivating value in the learning process. The flight vehicle, to be sure, may cover a wide spectrum of devices from helicopters to space craft; but all such devices have five elements in common:

(a) A propulsion system.
(b) A control and guidance system.
(c) An external shape of maximum aerodynamic efficiency.
(d) A structure of minimum weight and maximum strength.
(e) A suitable compromise among the elements (a) through (d), so as to produce a flight vehicle which best fulfills a given mission requirement.

Professional subjects embracing the five common elements form the heart of the engineering program. The professional subjects corresponding to elements (a) through (d) are offered in a generalized way so that they provide a substantial foundation for all forms of flight vehicles. Subjects corresponding to element (e) have as their objective bringing together the previous professional disciplines in the synthesis of a flight vehicle. Here students work under the close supervision of the staff to employ their creative skills to devise a vehicle which satisfies given mission requirements. More important, each student's critical technical judgment is exercised in making the necessary compromises among many conflicting technical requirements. His desire for individual specialization is satisfied by elective subjects.

The curriculum requirements for the Engineering Program are given below:

1. ENGINEERING PROGRAM CURRICULUM

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)			176
	PHYSICS 8.03 and 8.04 *or* 8.031 and 8.041[1] must be taken. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.		
DEPARTMENTAL PROGRAM			
	Required subjects		
16.81	FLIGHT VEHICLES	3 0 6	
3.14	ENGINEERING MATERIALS	4 2 4	
16.201	SOLID MECHANICS I	4 0 6	
16.20T	FLIGHT VEHICLE STRUCTURES I	4 0 6	
2.401	THERMODYNAMICS OF FLUID FLOW	3 0 6	
16.02	AERODYNAMICS	4 2 6	
16.11	FLIGHT VEHICLE AERODYNAMICS AND DYNAMICS	4 0 5	
16.53	PROPULSION	3 0 6	
16.01T	DYNAMICS	4 2 6	
6.43	INTRODUCTION TO ELECTRICAL SCIENCE	4 2 4	
6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4 0 6	
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3 0 9	
16.62	EXPERIMENTAL PROJECTS I	2 4 4	
16.71	FLIGHT VEHICLE ENGINEERING	2 3 7	
	THESIS	9	
			153
	Elective subjects		
	Unspecified		41
Total units required for the S.B. degree			370

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

ENGINEERING SCIENCE PROGRAM

The period since World War II has been one of intense change in flight vehicle technology.

The earliest airplane designers, although not ignorant of scientific methods, developed their machines largely by intuitive invention and empiricism. As the commercial and military usefulness of their product was demonstrated, there arose an intense desire to increase its performance and efficiency. This motivated intense research activity in the professional fields of propulsion, control and guidance, aerodynamics, and structures. The result is a new era in flight vehicle development in which scientific methods logically applied by teams have accomplished processes which were judged impossible a few years ago. Thus, research and the resulting development have become integral and highly important parts of flight vehicle technology. It is the purpose of the curriculum in the Engineering Science Program to prepare students to work at the frontiers of research for improvement of flight vehicles. The principal distinguishing feature of the engineering science curriculum is its emphasis on increased depth in the areas of physics, mathematics, gasdynamics and solid mechanics. Since a proper balance between theory and experiment is the keystone to progress in research and development, there is also emphasis on laboratory experience. Substantial elective time permits the student to reach more deeply into areas of his choice.

Like the engineering curriculum, the engineering science curriculum is designed as a terminal program. It is expected, however, that a rearrangement of Course content to permit a smooth transition into graduate work will be a common feature.

The curriculum requirements for the Engineering Science Program are as follows:

2. ENGINEERING SCIENCE PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS	(*see page 83*)				**176**
	PHYSICS 8.031 and 8.041[1] are prescribed. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.				
DEPARTMENTAL PROGRAM					
	Required subjects				
16.81	FLIGHT VEHICLES	3	0	6	
3.14	ENGINEERING MATERIALS	4	2	4	
16.201	SOLID MECHANICS I	4	0	6	
16.202	SOLID MECHANICS II	4	0	6	
2.401	THERMODYNAMICS OF FLUID FLOW	3	0	6	
16.03	GASDYNAMICS	4	2	6	
16.01T	DYNAMICS	4	2	6	
16.62	EXPERIMENTAL PROJECTS I	2	4	4	
16.63	EXPERIMENTAL PROJECTS II	2	6	4	
6.43	INTRODUCTION TO ELECTRICAL SCIENCE	4	2	4	
6.44	INTRODUCTION TO ELECTRICAL SCIENCE	4	0	6	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
18.06	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
	THESIS		9		
					150
	Elective subjects				
	Unspecified				**44**
Total units required for the S.B. degree					**370**

[1]8.041 must be followed by 8.051 (or 8.05).

The Honors Course

Students who wish to pursue a coordinated schedule of studies through their senior and graduate years may apply for the Honors Course group; a limited number of students of superior ability are selected each year for the group by the Department. A member of the Department aids each member in planning the senior and graduate schedules which are best suited to his individual interests. The program requires completion of all unit and humanities requirements for the Bachelor's degree and for either the Master's degree or the degree of Engineer in Aeronautics and Astronautics, but only a single thesis of not less than 30 units in the graduate program.

The Honors Course leads to the degree of Bachelor of Science in Aeronautics and Astronautics and either the degree of Master of Science in Aeronautics and Astronautics or the degree of Engineer in Aeronautics and Astronautics, awarded simultaneously at the end of the graduate program.

Aeronautics and Astronautics (Cooperative Course) (Course XVI-B)

The cooperative program for Aeronautics and Astronautics undergraduates provides the opportunity for about five months of experience in an industrial organization before the professional work of the senior year. Continuous contact with industrial problems enables students to discover and develop their aptitudes and interests to better advantage than would be possible with shorter periods of employment. The program does not interfere with the student's academic progress nor with his extracurricular activities in association with his classmates. It may be elected by students planning to take the Engineering Program or the Engineering Science Program.

The cooperating companies of the aircraft industry pay the students at prevailing rates

during their period of employment. The students pay their own expenses while away from the Institute.

Students who are interested in the program should apply to Department Headquarters for a set of Personnel Record Forms prior to December 1 of their sophomore year. These forms should be completed and returned by January, with an added statement specifying the location where the student prefers to work. Students who are selected become regular employees during their period of employment in an aircraft plant and are subject to the regulations of the company. They are expected to carry the Course through to completion unless exceptional circumstances intervene.

A list of the companies cooperating in this program is available at the Headquarters of the Department of Aeronautics and Astronautics.

Juniors in the Cooperative Course are also eligible for the Honors Course described above.

CURRICULUM IN THE COOPERATIVE COURSE (COURSE XVI-B)

The Cooperative Course leads to the degree of Bachelor of Science in Aeronautics and Astronautics. The curriculum requirements for this degree are the same as for Course XVI, except for the addition of required plant work:

16.85	INDUSTRIAL PRACTICE	40 h.p.w.

and, for the Engineering Science Program, the omission of 16.03, and the addition of:

16.02	AERODYNAMICS	4 2 6

GRADUATE STUDY IN AERONAUTICS AND ASTRONAUTICS

Graduate students in the Department of Aeronautics and Astronautics study and conduct research in the engineering and scientific aspects of many problems of flight transportation. Fields of endeavor may be fairly general; programs may be oriented to aeronautical or astronautical engineering or to aeronautics or astronautics, in which case there will be less emphasis on engineering applications. Major fields of specialization include vehicle design and operation, aerodynamics or gas dynamics, space mechanics, structures, aeroelasticity, propulsion, instrumentation, and automatic control. For successful graduate work in any of these fields, strong preparation and aptitude in applied mathematics and physics are necessary foundations. Students may elect subjects in other departments which bear a useful relation to their program.

Advanced study in the Department leads to the degrees of Master of Science in Aeronautics and Astronautics, Engineer in Aeronautics and Astronautics, Materials Engineer, Doctor of Science or Doctor of Philosophy in Aeronautics and Astronautics, and Doctor of Science in Materials Engineering.

Entrance Requirements for Graduate Study

In addition to the general requirements for admission to the Graduate School, all applicants must have completed strong fundamental undergraduate subjects in thermodynamics, mechanics, electrical engineering, and automatic control. Additional undergraduate preparation is a prerequisite for specialization in particular fields. Some prerequisites may be completed early in a graduate program.

The Graduate Degrees

MASTER OF SCIENCE IN AERONAUTICS AND ASTRONAUTICS

For this degree, at least one year of an approved graduate program is required, including thesis. Two terms of advanced mathematics beyond DIFFERENTIAL EQUATIONS (18.04) or its equivalent must be included. This degree is also awarded simultaneously with the Bachelor of Science in Aeronautics and Astronautics upon successful completion of the five-year Honors Course program.

Although excessive specialization is undesirable, it is expected that most candidates for this degree will concentrate in a single professional field, not seeking the same breadth of educational background implied by the Engineer degree.

ENGINEER IN AERONAUTICS AND ASTRONAUTICS

For this degree the student must satisfactorily complete at least two years of an approved graduate program, including thesis. Subjects in a variety of professional specialties are required, so as to provide a broad foundation in both aeronautical and astronautical science and their engineering applications.

Requirements for admission to candidacy for the degree of Engineer in Aeronautics and Astronautics are more rigorous than for the degree of Master of Science in Aeronautics and Astronautics.

DOCTOR OF SCIENCE (OR PHILOSOPHY) IN AERONAUTICS AND ASTRONAUTICS

To be recommended for this degree by the Department of Aeronautics and Astronautics,

the student must complete an approved program, including a thesis. Such a program probes more deeply into a special field than the program for the Engineer degree and does not necessarily include the same breadth of engineering applications. Competence must be demonstrated by a Qualifying Examination designed to test the candidate's grasp of the principles of mathematics and physics and their application to a simple new situation. A General Examination later tests the depth of the candidate's understanding of his major field of study. The thesis must demonstrate the student's ability to carry out independent original research of high quality on a problem of aeronautical or astronautical science or engineering.

DOCTOR OF SCIENCE WITH SPECIALIZATION IN THE FIELD OF INSTRUMENTATION

For the Doctor's degree in this field, the student is required to complete an approved program, including thesis, in the interrelated professional fields of instrumentation. This work involves the cooperative effort of the Departments of Aeronautics and Astronautics (Instrumentation and Weapons Systems Divisions), Electrical Engineering, Mechanical Engineering, Mathematics, and Physics. The program is administered, for registration purposes, by the Department of Aeronautics and Astronautics. The General Examination includes both written and oral parts. The thesis must demonstrate the ability of the student to do original research of high grade on a problem of instrumentation or weapons systems engineering.

MATERIALS ENGINEER AND DOCTOR OF SCIENCE IN MATERIALS ENGINEERING

There has arisen in recent years a very strong interaction between the field of materials and flight vehicle development. It may be said that material properties impose limitations on either the performance or efficiency of most flight vehicles and their propulsion systems. Graduates who have preparation in the combined fields of aeronautics and astronautics and material science are required in increasing numbers to deal with these important interdisciplinary problems.

Graduate students with undergraduate backgrounds in aeronautics and astronautics may pursue programs leading to the degrees of Materials Engineer or Doctor of Science in Materials Engineering. The same general requirements for the completion of these degrees are applicable as for the corresponding degrees in Aeronautics and Astronautics.

Programs of study leading to the degrees of Materials Engineer and Doctor of Science in Materials Engineering are arranged on an individual basis, depending upon the preparation of the student. In general, such programs will involve a substantial number of subjects in the fields of metallurgy, physics, and chemistry in addition to subjects within the Department.

Language Requirement

No language requirement is made for candidates for the Master of Science or Engineer degrees. A candidate for the Doctor of Science degree must demonstrate competence in reading two foreign languages in his major field. Each student's choice of languages must be approved by his Graduate Registration Officer.

Financial Assistance for Graduate Study

The Department offers several fellowships for full-time study in aeronautics and astronautics; these are described in Appendix A of this Catalogue. In addition, graduate students may earn part or all of their expenses as part- or full-time assistants. These duties, concerned with either teaching or research, provide valuable educational experience.

Department of Chemical Engineering

(Including the School of Chemical Engineering Practice)

EDWIN RICHARD GILLILAND, SC.D., D.ENG.
Professor of Chemical Engineering; Head of the Department

WARREN KENDALL LEWIS, PH.D., D.SC., D.ENG.
Professor of Chemical Engineering, Emeritus

HOYT CLARKE HOTTEL, A.B., S.M.
Professor of Fuel Engineering; Director of the Fuels Research Laboratory

THOMAS KILGORE SHERWOOD, SC.D., ENG.D.
Professor of Chemical Engineering

HAROLD CHRISTIAN WEBER, D.SC.
Professor of Chemical Engineering, Emeritus; Lecturer

HERMAN PAUL MEISSNER, D.SC.
Professor of Chemical Engineering

GLENN CARBER WILLIAMS, SC.D.
Professor of Chemical Engineering

JOHNSON EDWARD VIVIAN, SC.D.
Professor of Chemical Engineering

HAROLD SOMERS MICKLEY, SC.D.
Professor of Chemical Engineering

CHARLES NELSON SATTERFIELD, SC.D.
Professor of Chemical Engineering

ALAN SHERMAN MICHAELS, SC.D.
Professor of Chemical Engineering

RAYMOND FREDERICK BADDOUR, SC.D.
Associate Professor of Chemical Engineering

ROBERT CLARK REID, SC.D.
Associate Professor of Chemical Engineering; Director of the School of Chemical Engineering Practice; Director of the Oak Ridge Engineering Practice School

EDWARD WILSON MERRILL, SC.D.
Associate Professor of Chemical Engineering

DANIEL FURTH FAIRBANKS, SC.D.
Assistant Professor of Chemical Engineering

PIERRE LEONCE THIBAUT BRIAN, SC.D.
Assistant Professor of Chemical Engineering; United Engineers and Constructors, Inc., Preceptor

CHARLES MICHAEL MOHR, SC.D.
Assistant Professor of Chemical Engineering

CARY JUDSON KING, III, SC.D.
Assistant Professor of Chemical Engineering

RONALD ELLIS ROSENSWEIG, SC.D.
Assistant Professor of Chemical Engineering

HARRIS JACOB BIXLER, SC.D.
Assistant Professor of Chemical Engineering; Director of the Bound Brook Station, School of Chemical Engineering Practice

JAMES ABBOTT LARRIMORE, B.ENG.
Assistant Professor of Nuclear Engineering; Director of the Engineering Practice School of Oak Ridge

JAMES ALEXANDER BARRIE, PH.D.
Assistant Professor of Chemical Engineering (Visiting)

KENNETH ALAN SMITH, S.M.
Assistant Professor of Chemical Engineering

WOLF RANDOLPH VIETH, SC.D.
Assistant Professor of Chemical Engineering; Director of the Bayway Station, School of Chemical Engineering Practice

HENRY ARON BECKER, S.M.
Assistant Professor of Chemical Engineering

Technical Instructors

HENRY CHASEN
HAROLD HAVNER CARTER

Research Associates

PETER HARROLD DUNDAS, PH.D.
FRANK FEAKES, SC.D.

Professors Emeriti

WARREN KENDALL LEWIS, PH.D., D.SC., D.ENG.
Professor of Chemical Engineering, Emeritus

WILLIAM HENRY McADAMS, D.SC.
Professor of Chemical Engineering, Emeritus

WALTER GORDON WHITMAN, SC.D.
Professor of Chemical Engineering, Emeritus

HAROLD CHRISTIAN WEBER, D.SC.
Professor of Chemical Engineering, Emeritus, Lecturer

STATIONS OF THE SCHOOL OF CHEMICAL ENGINEERING PRACTICE

Directors

WOLF RANDOLPH VIETH, SC.D., *Bayway*
HARRIS JACOB BIXLER, SC.D., *Bound Brook*

Assistant Directors

ROBERT NED GURNITZ, S.M., *Bayway*
ROBERT MITCHELL HODGES, JR., S.M., *Bound Brook*

CHEMICAL ENGINEERING

Chemical engineers have contributed notably to the development of process industries such as chemicals and petroleum. These industries are now rapidly expanding in such areas as synthetic organics, microbiology, pharmaceuticals, plastics, petrochemicals, new metals, and atomic energy. The chemical engineer must be equipped to do more than handle present problems; he must understand the principles involved in new developments and be prepared to pioneer in unknown areas. The Department's primary aim is to cultivate its students' capacities for handling new problems with competence.

The Chemical Engineering Department offers undergraduate programs leading to either of two Bachelor of Science degrees: one in Chemical Engineering (Course X) and one in Chemical Engineering Practice (Course X-B). This latter includes one term of study at field stations in industry. In addition, there is a wide selection of graduate subjects and research leading to advanced degrees in Chemical Engineering and Chemical Engineering Practice. The interests and offerings of the staff range broadly over the fields of process engineering and applied chemistry and include specializations in engineering operations, applied chemistry, and fuel engineering. This breadth permits students considerable selectivity in advanced phases of undergraduate work and in graduate study.

The various stations of the School of Chemical Engineering Practice and the Engineering Practice School at Oak Ridge offer unique opportunities for students to develop capabilities to apply basic professional principles to the solution of practical problems of industry. These Schools involve one term of work under the direction of Institute faculty at the Practice School stations. They are generally included in a program for an advanced degree, but the School of Chemical Engineering Practice is also available for undergraduates in the second term of the senior year. The program of the Engineering Practice School at Oak Ridge has special value for graduate students in nuclear engineering and chemical engineering.

THE UNDERGRADUATE CURRICULA

The undergraduate Courses provide 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 each student considerable latitude in arranging a selection of subjects that will best fit his needs and develop his aptitudes. Those who expect to go on to Graduate School may therefore elect subjects which will strengthen their preparation for advanced work.

The student takes a significant professional minor, which may be equivalent to as much as one-and-a-half terms of full-time study. This minor may be in any one of a number of areas, such as automation, biochemistry, computers, economics, electronics, fluid mechanics, geophysics, industrial management, metallurgy, pregraduate nuclear engineering, and properties of materials. Each student plans his program in the second year, with the guidance of his faculty counselor. Counseling in the selection of programs is available, and illustrative programs are provided by the Department.

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 his breadth of outlook and understanding of society.

These curricula are designed to give undergraduates a sound basis for further developing their aptitudes and interests through industrial work, independent study, or graduate work.

Chemical Engineering (Course X)

The Course in Chemical Engineering leads to the degree of Bachelor of Science in Chemical Engineering. The curriculum requirements for the degree are given below:

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)					176
PHYSICS 8.03 and 8.04 *or* 8.031 and 8.041[1] must be taken.					
DEPARTMENTAL PROGRAM					
Required subjects					
5.41	ORGANIC CHEMISTRY I	4	0	4	
5.416	ORGANIC PREPARATIONS I	1	5	0	
10.12	CHEMICAL ENGINEERING	3	0	5	
10.15	THESIS REPORTS	0	3	0	
	THESIS		12		37
Elective subjects					
In specified areas:					
	Chemistry	at least 35			
	Chemical engineering	at least 60			
	Professional minor	at least 25			
	Laboratory work (within the above electives or in addition thereto)	at least 23			
	Unspecified elective subjects as needed to fulfill the total unit requirement of				161
Total units required for the S.B. degree					374

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

Electives in chemistry are normally selected from the following: a second term of organic chemistry (5.42); two terms in the area of physical chemistry or chemical physics (8.051 and 5.62, or 8.051 and 8.052); a term each of inorganic chemistry (5.03) and analytical chemistry (5.14); and the relevant laboratory subjects. Electives in chemical engineering normally include most of the following: a second term of thermodynamics (10.13), fluid mechanics (10.30), engineering operations (10.31 and 10.32), structure and properties of non-metallic substances (10.21), industrial chemistry (10.18), and industrial chemistry laboratory (10.26) or chemical engineering laboratory (10.27). Additional opportunity for experimental research, with considerable flexibility in scheduling, is provided in 10.91.

Chemical Engineering Practice (Course X-B)

The facilities of the School of Chemical Engineering Practice are available to a selected group of undergraduates during the second half of their senior year. The nature of the work at the Practice School stations is described in the section on graduate education in chemical engineering. Students who wish to study in this Course should so register in the first term of their fourth year; those accepted will spend the second term at the field stations. The Course leads to the degree of Bachelor of Science in Chemical Engineering Practice.

The curriculum requirements for this degree are the same as those in Chemical Engineering (Course X), except that (1) subjects 10.83 and 10.84 (the two Practice School stations) are required; (2) THESIS REPORTS (10.15) is not required; and (3) the minimum number of elective units which are required in the following areas are:

Chemical engineering	45
Professional minor	15
Laboratory work	13

GRADUATE STUDY IN CHEMICAL ENGINEERING

Because of the breadth of the field of chemical engineering, the undergraduate Course must be devoted primarily to training in fundamentals; strictly professional subjects are necessarily elementary in character. Postgraduate study is therefore of particular importance and value to the chemical engineer.

The following advanced degrees are offered in chemical engineering: Master of Science in Chemical Engineering, Master of Science in Chemical Engineering Practice, Chemical Engineer, Materials Engineer, Doctor of Science or Doctor of Philosophy in Chemical Engineering, and Doctor of Science in Materials Engineering. Programs for the Master of Science degree are usually arranged as a continuation of undergraduate professional training on a more mature basis. Work for the Engineer and doctoral degrees is more specific in character, and the Department offers coordinated programs in three fields: engineering operations, applied chemistry, and fuel engineering. Special programs are developed for individual cases.

Entrance Requirements for Graduate Study

In addition to the general requirements for admission to the Graduate School set forth in Section 3 of this Catalogue, preparation in physical chemistry and organic chemistry equivalent to PHYSICAL CHEMISTRY I and II (5.61, 5.62) and ORGANIC CHEMISTRY I and II (5.41, 5.42) is normally essential.

Requirements for Advanced Degrees

The general requirements for the various degrees are specified in Section 3. Departmental language requirements for the doctorate are a reading knowledge of scientific literature in English and in two modern languages. The two modern languages must be approved by the Graduate Registration Officer of the Department as having adequate literature in the chemical engineering field.

Fields of 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.

ENGINEERING OPERATIONS (PROCESS ENGINEERING)

The variety of graduate offerings provides opportunity for programs in heat transfer, fluid mechanics, and the separation processes based on mass transfer — subjects which are basic in

process engineering. The topics include thermodynamics, applied mathematics, molecular transport properties, fluid mechanics and the interrelation of mass, momentum and heat transfer, distillation, mass transfer between phases, combustion, economic balance, and plant design. Opportunities for research of an advanced nature are available.

Relevant subjects offered by the Department include:

ANALYTICAL TREATMENT OF CHEMICAL ENGINEERING PROCESSES (10.33)
CHEMICAL ENGINEERING THERMODYNAMICS (10.40)
DISTILLATION (10.41)
ABSORPTION AND EXTRACTION (10.46)
ION EXCHANGE (10.47)
HEAT TRANSMISSION (10.50)
CHEMICAL ENGINEERING II (10.52)
CHEMICAL ENGINEERING DESIGN (10.53)
ECONOMIC BALANCE IN CHEMICAL INDUSTRY (10.55)
PRINCIPLES OF COMBUSTION (10.70)

Programs may also include advanced subjects in mathematics, instrumentation, fluid mechanics, metallurgy, and others offered in other departments.

APPLIED CHEMISTRY

The Department offers a diversified program in applied chemistry, designed for the student who wants to broaden his competence in the chemical aspects of chemical engineering. This program provides subjects in industrial chemistry and chemical thermodynamics; in chemical kinetics and theory of rate-processes, with emphasis on heterogeneous and catalytic processes; in colloidal and surface-chemistry; in the technology of high polymer synthesis and fabrication; in molecular forces and properties of matter; and in the physical chemistry of ion-exchange, adsorption, and chromatography. Much of the Department's research activity falls into these areas, and unique laboratory facilities are provided.

Relevant subjects offered by the Department include:

INDUSTRIAL CHEMISTRY (10.25)
ION EXCHANGE (10.47)
ADVANCED THERMODYNAMICS (10.62)
STRUCTURE AND PROPERTIES OF POLYMERS (10.64)
APPLIED CHEMICAL KINETICS (10.65)
COLLOID CHEMISTRY (10.66)
APPLIED SURFACE CHEMISTRY (10.67)
POLYMER CHEMISTRY (10.68)
HIGH POLYMER TECHNOLOGY (10.69)

A well-rounded program in applied chemistry might also include subjects given by other departments in advanced organic, inorganic, or physical chemistry; in biochemistry, enzymology, or bacteriology; and in physical metallurgy, electrochemistry, corrosion, or ceramics.

FUEL ENGINEERING

Among all the chemical reactions, combustion is the one most widely used — in chemical synthesis, chemical and metallurgical processing, and power production. An integrated program in this field would typically include subjects in heat, momentum and mass transfer, thermodynamics, kinetics, combustion, furnaces, a seminar in combustion, and a research problem in fuel processing or combustion. The Department's Fuels Research Laboratory provides excellent facilities for research on a wide range of problems, from small-scale studies of fuel processing or combustion kinetics to research in high-output combustion in rockets, ramjets, and gas turbines requiring use of the Laboratory's 2000 KW compressors to simulate altitudes to 80,000 feet and flight Mach numbers to 2.5.

Subjects commonly taken are:

CHEMICAL ENGINEERING THERMODYNAMICS (10.40)
CHEMICAL ENGINEERING II (10.52)
APPLIED CHEMICAL KINETICS (10.65)
PRINCIPLES OF COMBUSTION (10.70)
SELECTED COMBUSTION PROBLEMS (10.72)
RADIATIVE TRANSFER (10.74)

SCHOOL OF CHEMICAL ENGINEERING PRACTICE

In the School of Chemical Engineering Practice, selected groups of graduate students spend a term at two field stations located in industrial plants at Bayway and Bound Brook, New Jersey. At each field station, the student groups operate under the direction of two members of the Institute staff. The facilities of the plant constitute their laboratory. The program's chief objective is to develop students' ability to apply theory to practical engineering accomplishment. Staff guidance emphasizes resourcefulness and effectiveness in cooperative effort under industrial conditions.

Quantitative aspects of chemical engineering are intensively studied in the Practice School. Plant investigations are carried out by the students on special phases of unit operations and on problems of industrial chemistry particularly important at the station in question. Oral and written presentation of plans, results, and recommendations for action are stressed.

Bachelor's graduates of this Department ordinarily meet the requirements for the S.M. degree

in Chemical Engineering Practice (Course X-A) in two terms. Starting in the September following graduation, students are at the field stations in Bayway and Bound Brook (10.85, 10.86 and 10.87, 10.88) until the end of January, and then return to the Institute to complete the program for the Master's degree during the spring term.

A similar Practice School program at the field stations starts early in February and extends to early June.

The Engineering Practice School at Oak Ridge, described in Section 1 of this Catalogue, is similar in educational philosophy and technique to the School of Chemical Engineering Practice and operates on the same schedule. For chemical engineering students it may be regarded as an alternative experience to that of the School of Chemical Engineering Practice.

For students who have graduated in chemical engineering from other institutions, the usual program of study for the Master's degree in Chemical Engineering Practice involves one or 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. Students are usually not admitted to the Practice School until they have spent at least one term at the Institute.

Department of Civil and Sanitary Engineering

ROLF ELIASSEN, SC.D.
Professor of Sanitary Engineering; Acting Head of the Department

CHARLES HEAD NORRIS, SC.D.
Professor of Structural Engineering; Executive Officer

WILLIAM EDWARD STANLEY, C.E.
Professor of Sanitary Engineering, Emeritus; Lecturer

ARTHUR THOMAS IPPEN, PH.D.
Professor of Hydraulics

ALBERT GEORGE HENRY DIETZ, SC.D.
Professor of Building Engineering

JAMES WALLACE DAILY, PH.D.
Professor of Hydraulics

ROBERT JOSEPH HANSEN, SC.D.
Professor of Structural Engineering

MYLE JOSEPH HOLLEY, JR., S.M.
Professor of Structural Engineering

THOMAS WILLIAM LAMBE, SC.D.
Professor of Soil Engineering

EUGENE MIRABELLI, S.B.
Associate Professor of Structural Design

ALEXANDER JAMIESON BONE, S.M.
Associate Professor of Transportation Engineering

JOHN MELVIN BIGGS, S.M.
Associate Professor of Structural Engineering

DONALD ROBERT FERGUSSON HARLEMAN, SC.D.
Associate Professor of Hydraulics

CHARLES LESLIE MILLER, S.M.
Associate Professor of Surveying

ROBERT VAN DUYNE WHITMAN, SC.D.
Associate Professor of Soil Engineering

GEORGE THOMAS BRYANT, A.B., M.S.
Associate Professor of Sanitary Engineering

FREDERICK JEROME McGARRY, A.B., S.M.
Associate Professor of Materials

PETER STURGES EAGLESON, SC.D.
Associate Professor of Hydraulic Engineering

FRANK JOSEPH HEGER, JR., S.M.
Assistant Professor of Structural Design

ALBERT SCHEFFER LANG, S.B.
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JAMES MARTIN SYMONS, SC.D.
Assistant Professor of Sanitary Engineering

PERRY LEE McCARTY, SC.D.
Assistant Professor of Sanitary Engineering

EGONS TONS, S.M.
Assistant Professor of Transportation Engineering

PAUL OSBORNE ROBERTS, JR., S.M.
Assistant Professor of Civil Engineering

MARTIN WOHL, S.M.
Assistant Professor of Transportation Engineering

ZVI GOETZLER, M.S.
Assistant Professor of Soil Mechanics (Visiting)

SENOL UTKU, SC.D.
Assistant Professor of Structural Engineering (Visiting)

RODNEY DENLINGER ANDREWS, JR., PH.D.
Assistant Professor of Materials

CHARLES CUSHING LADD, SC.D.
Assistant Professor of Soil Engineering

JOHN FISHER KENNEDY, PH.D.
Assistant Professor of Hydraulics

Instructors

DANIEL RITTENHOUSE SCHURZ, B.A., S.M.
JOHN LLOYD CUTCLIFFE, S.M.
EDWIN PHILLIP GLADDING, S.B., B.A.
C. ANDREW PRETZER, B.S.E.

Technical Instructor

ALBERT JOSEPH O'NEILL, S.B.

Research Associates

JACOB JOSEPH BIKERMAN, PH.D.
ROBERT TORRENCE MARTIN, PH.D.

Professors Emeriti

CHARLES MILTON SPOFFORD, S.B.
Hayward Professor of Civil Engineering, Emeritus

JOHN BRAZER BABCOCK, 3D, S.B.
Professor of Railway Engineering, Emeritus

WILLIAM EDWARD STANLEY, C.E.
Professor of Sanitary Engineering, Emeritus; Lecturer

CIVIL AND SANITARY ENGINEERING

Among trends that point the way to the future are the rapid tempo of scientific and technological advance, the explosion of population, and the rate at which we are plundering our natural resources. Closely associated is the rate at which man seems to be poisoning — or in some instances strangling — the environment in which he lives. Radioactive wastes, water shortages, smog, obsolescent structures, and traffic congestion may all be cited as among the problems that must be faced by civil engineers. Such problems have two common denominators: they all deal with human needs on a large scale; and they all deal with man's environment. Civil engineering at M.I.T. centers on the fulfillment of human needs through the adaptation and control of the land-water-air environment.

Since it deals with man as well as with his environment, civil engineering is based not only on the physical sciences — as are all the branches of engineering — but on the earth, life, and social sciences as well. Building from these roots, the civil engineer is concerned with the engineering of the structures, ground facilities, and processes that comprise and control environment. But today he must go beyond this; to truly serve man's needs, these components must be integrated into systems such as those involved in water resources and transportation — systems that involve social as well as physical forces.

Modern technology, which is partly responsible for some of our great environmental problems, also provides powerful tools to yield solutions to these problems. Civil engineering at M.I.T., in bringing these tools to bear, is the instigator of significant change in the engineering of man's environment. As such, it is of particular interest to young men who are not only challenged by the intellectual rigor of science and mathematics but who are also motivated to exploit the frontiers of science and technology on a large-scale basis for the direct benefit of people.

Facilities

The Department of Civil and Sanitary Engineering has excellent facilities for work in all phases of the field. The Structural Analysis Laboratory offers facilities for instruction and research in the static and dynamic behavior of structures. The Soil Mechanics Laboratory is available for instruction in experimental technique and for investigations of soils of various kinds. The Hydrodynamics Laboratory has facilities for fundamental studies in fluid mechanics and special investigations on hydraulic models. A newly equipped Transportation Laboratory and a new Data Engineering Laboratory offer research facilities in these areas. The basic facilities of the Data Engineering Laboratory are an IBM 1620 electronic computer and a well-equipped Photogrammetry Laboratory. The Sedgwick Laboratories of Sanitary Science are devoted to instruction and research in the scientific discipline comprising sanitary engineering. The Building Materials Laboratory has facilities for investigating the fundamental properties of engineering materials, including concrete; cementitious materials; timber products; and plastics and laminates, the new synthetics.

THE UNDERGRADUATE CURRICULUM

Civil Engineering (Course I)

The undergraduate curriculum in civil engineering at M.I.T. is deeply rooted in science and in mathematics. It is designed to develop lasting values in terms of engineering accomplishment. It provides a strong background for continuation into graduate school. And it also, with its five unrestricted elective subjects — the equivalent of a full term's work — is adaptable to the needs of a four-year program.

The Departmental Requirements may be classified into the following five areas:

(1) A strong core in the engineering of the physical sciences.
(2) Subjects in the engineering of the "environmental sciences" — namely, the earth, life, and social sciences.
(3) Two terms of advanced mathematics for engineering design.
(4) Two terms of engineering, with emphasis on civil engineering components and systems.
(5) The electives which, while normally used for such professional subjects in civil engineering as structures, transportation, construction materials, and hydraulic engineering, also provide flexibility for students who may desire to take some subjects in areas such as city planning or industrial management — or in modern physics or a further pursuit of electrical engineering.

The subjects in the environmental sciences are all new: GEOTECHNICAL SCIENCE (1.01), covering the basic principles of the earth sciences, from the standpoint of their implication to engineered construction projects; HUMAN ECOLOGY AND ENGINEERING (1.02T), leading to the inter-

relationship of the environment and man's functions, and the engineering control of environment; and SOCIAL AND POLITICAL FACTORS IN ENGINEERING (1.03), dealing with case studies of policy-making processes involved in civil engineering projects such as transportation, water resources, and urban redevelopment.

Advanced mathematics includes ELEMENTARY STATISTICS (18.10), important in all branches of civil engineering; and MATHEMATICAL METHODS IN CIVIL ENGINEERING (1.04), a synthesis of modern mathematical methods of formulating and solving civil engineering problems, including the organization of problems in computation, and computer methods as applied to engineering.

The two terms of engineering cover the formulation and solution of engineering problems utilizing the formal approaches of systems engineering and rational design. The engineering aspect of the program is greatly strengthened by the use of elective time for professional subjects in civil engineering.

Most of the Institute's work in sanitary engineering and in building engineering and construction is given at the graduate level (Courses XI and XVII, respectively). Civil Engineering (Course I) is the proper undergraduate preparation for these areas as well as for graduate work in civil engineering.

The Course leads to the degree of Bachelor of Science in Civil Engineering. The curriculum requirements for this degree are given below.

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)		**176**
	PHYSICS 8.03 and 8.04 are taken except when plans for further study clearly indicate the need for the subject matter of 8.031 and 8.041.[1] ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.	
DEPARTMENTAL PROGRAM		
	Required subjects	
	Environmental Sciences	
1.01	GEOTECHNICAL SCIENCE 3 1 5	
1.02T	HUMAN ECOLOGY AND ENGINEERING 3 3 3	
1.03	SOCIAL AND POLITICAL FACTORS IN ENGINEERING 3 0 6	
	Mathematical Methods	
18.10	ELEMENTARY STATISTICS 3 0 6	
1.04	MATHEMATICAL METHODS IN CIVIL ENGINEERING 3 2 4	
	Engineering Science	
2.01	MECHANICS OF SOLIDS I 3 0 5	
2.02	MECHANICS OF SOLIDS II 3 0 5	
1.05	FLUID DYNAMICS 3 2 5	
1.06	PARTICULATE MECHANICS 3 2 5	
	Required subjects (continued)	
	Engineering	
1.07	ENGINEERING I 3 3 3	
1.08	ENGINEERING II 3 3 3	
	THESIS 9	
		108
	Elective subjects	
	In specified areas 32	
	An approved program composed of one subject in each of the following areas:	
	Electrical engineering Materials engineering Thermodynamics	
	Unspecified[2] 54	
		86
Total units required for the S.B. degree		**370**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

[2] This portion of the program should be formulated in accordance with the student's over-all professional objectives, and should reflect his plans with respect to possible graduate study.

Available electives in various fields of civil engineering include the subjects listed below. Students may also wish to consider other graduate (A) subjects for which they have the proper prerequisites.

1.11	INTRODUCTION TO PHOTOGRAMMETRY (3–2–4) U
1.20	TRANSPORTATION ENGINEERING (3–0–6) G
1.25	ROUTE LOCATION (2–0–4) G(A)
1.26	GROUND FACILITIES FOR AIR TRANSPORTATION (3–0–6) G(A)
1.321	SOIL BEHAVIOR (2–3–5) G(A)
1.39	SPECIAL STUDIES IN SOIL ENGINEERING (*) G(A)
1.43T	ADVANCED MATERIALS (3–2–4) U
1.511	STRUCTURAL ANALYSIS AND DESIGN I (3–2–5) U
1.512	STRUCTURAL ANALYSIS AND DESIGN II (3–2–5) U
1.71	HYDROLOGY (3–0–6) G(A)
1.72	HYDRAULIC ENGINEERING (3–0–6) G
1.921	BUILDING CONSTRUCTION (3–0–3) U
1.931	DWELLING HOUSE CONSTRUCTION (3–0–3) U
17.42	CONSTRUCTION ANALYSIS SEMINAR (2–0–4) G(A)
17.73	MATERIALS — WOOD, PLASTICS, FABRICS (3–0–3) U
17.771	CEMENTITIOUS MATERIALS (3–2–4) G(A)

THE GRADUATE PROGRAMS

The Department of Civil and Sanitary Engineering provides opportunity for graduate study and research leading to the degrees of Master of Science in Civil Engineering, Civil Engineer, and Doctor of Science in Civil Engineering. It also offers graduate programs in Sanitary Engineering (Course XI), in Building Engineering and Construction (Course XVII), and in Materials Engineering.

Students may undertake graduate study either on a full-time basis or on a part-time basis in connection with a junior staff appointment. Financial aid is available to full-time students in the form of fellowships, scholarships, or loans. (See Section 3 and Appendix A.)

* Time arranged.

Civil Engineering (Course I)

Programs of study in civil engineering may be selected from the following fields:

Structural Engineering: advanced subjects dealing with analysis and design of statically indeterminate and other complex structures.

Soil Engineering: theoretical and experimental work dealing with soils and soil structures.

Hydraulics: theoretical and experimental fluid mechanics; hydraulic engineering; water resources.

Transportation Engineering: design and operation of highways and airports; advanced photogrammetry.

Students may supplement their programs in these fields with approved subjects in sanitary engineering and building engineering and construction, and with approved subjects in related fields, such as mathematics, mechanics, materials, geology, nuclear engineering, and industrial management.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

In addition to the general requirements set forth in Section 3 of this Catalogue, applicants must present evidence of sufficient undergraduate training to prepare them for the advanced subjects which they wish to take. This training generally will include two terms of applied mechanics plus additional preparation for specific areas of graduate study, as given below.

For Fluid Mechanics and Hydraulic Engineering: One term of fluid mechanics.

For Soil Engineering: One term of soil mechanics.

For Structural Engineering: One term of materials and two terms of structural analysis and design, including consideration of statically indeterminate structural types.

Students may make up deficiencies in prerequisites while pursuing a program of graduate work; they must remove any deficiencies before proceeding with advanced subjects dependent upon the prerequisites.

MASTER OF SCIENCE IN CIVIL ENGINEERING

At the discretion of the Department, up to 24 units of the more advanced subjects in the undergraduate curricula may be accepted in partial fulfillment of the requirements for the degree of Master of Science.

CIVIL ENGINEER

Programs of study leading to the degree of Civil Engineer provide opportunities for a broader training than that required for the Master's degree and better preparation for professional practice in civil engineering. The rigor of the program and the quality of academic performance required are substantially those demanded of students working toward the Master's degree or those preparing for the General Examination for the Doctor's degree. The normal period of study for this degree is two full years beyond the Bachelor's degree.

DOCTOR OF SCIENCE IN CIVIL ENGINEERING

Only students who have shown promise of outstanding performance in work of a creative nature are encouraged to study for the doctorate. Students beginning graduate work whose records do not show this ability are usually advised to qualify first for the Master's or Engineer degree. The thesis research for the doctorate is expected to make a contribution to professional knowledge in the field of civil engineering.

General requirements for the Doctor's degree are given in Section 3 of this Catalogue.

Each applicant for the doctorate in civil engineering is required to demonstrate his ability to read scientific literature in English and in two other modern languages, with German and either French or Russian usually specified.

Sanitary Engineering (Course XI)

The Department offers graduate study and research in sanitary engineering as Course XI, to satisfy the requirements for the degrees of Master of Science in Sanitary Engineering, Sanitary Engineer, and Doctor of Science in Sanitary Engineering.

Special sanitary engineering subjects are offered dealing with: water resources and treatment; sewage, refuse and industrial waste processing and disposal; air pollution control; sanitary chemistry and chemical examination of water, sewage and industrial wastes; sanitary microbiology and other applications of biochemistry; environmental sanitation; radiological health; and public health engineering.

Civil engineering subjects of value to sanitary engineers are also offered, such as advanced hydraulics, soil mechanics and foundations, structural theory and design, and others. In addition, a number of closely related subjects in other departments may be pursued to complete a particular plan of study.

Programs of study may be arranged to provide the fundamental training required for professional careers in the special fields of sanitary engineering, including: engineering design and construction of sanitary facilities, and consulting

engineering practice; process or functional design for water, sewage, and industrial waste treatment, refuse disposal and stream sanitation; operation and management of waterworks, sewage treatment plants, and other sanitary facilities and services; and environmental sanitation with private corporations or in public health agencies.

SANITARY ENGINEERING LABORATORIES

The Sedgwick Laboratories of Sanitary Science provide well-equipped facilities for instruction and research in sanitary chemistry; sanitary biology and biochemistry; environmental sanitation in relation to nuclear energy; and engineering problems relating to water, sewage, and industrial waste treatment.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

In general, graduates of approved programs in civil engineering will have the necessary undergraduate background for graduate study leading to a career in any of the special fields of sanitary engineering. Graduates of approved programs in chemical engineering will be well prepared to take up sanitary engineering in the fields of industrial wastes and environmental sanitation; but if they desire to prepare for sanitary engineering design and construction, they should include additional studies in hydraulics and structural theory as part of their graduate programs. A graduate in any other field of engineering or in chemical or biological science will need additional undergraduate preparation, depending upon his previous training and the program of study proposed; or, he may qualify for study leading to a degree without specification of a field.

Students whose undergraduate training has been in some other field, such as chemical engineering, may substitute for civil engineering subjects other subjects well adapted to preparing a sanitary engineer for process work such as the treatment of industrial wastes.

MASTER OF SCIENCE IN SANITARY ENGINEERING

Up to 24 units of certain of the subjects listed above may be accepted, at the discretion of the Department, in partial fulfillment of the requirements for the degree of Master of Science in Sanitary Engineering. Students with proper undergraduate preparation normally complete the requirements for the degree in two terms.

SANITARY ENGINEER

Programs of study leading to the degree of Sanitary Engineer provide opportunities for a broader education than that required for the Master's degree and better preparation for professional practice in sanitary engineering. The quality of academic performance required is substantially that demanded of students working toward the Master's degree or preparing for the General Examination for the Doctor's degree. The normal period of study for this degree is two full years beyond the Bachelor's degree.

DOCTOR OF SCIENCE IN SANITARY ENGINEERING

Only students who have shown promise of outstanding performance in work of a creative nature are encouraged to study for the doctorate. Students beginning graduate work whose records do not yield evidence of this ability are usually advised to qualify first for the Master's degree. The thesis research for the doctorate is expected to make an original contribution to professional knowledge in the field of sanitary engineering.

The general requirements for the Doctor's degree are those given in Section 3.

Each applicant for the doctorate in sanitary engineering is required to demonstrate his ability to read scientific literature in English and in two other modern languages, with German and French usually preferred.

Building Engineering and Construction (Course XVII)

The Department of Civil and Sanitary Engineering offers in Course XVII opportunities for graduate study and research in building engineering and construction leading to the degrees of Master of Science in Building Engineering and Construction, and Building Engineer.

Programs for graduate study are flexible, and students are encouraged to work out individual plans with Registration Officers. With the subjects in Building Engineering and Construction as a core (see Number 17 in the "Descriptions of Subjects" Section of this Catalogue), and with subjects in materials and construction in Civil Engineering, students may select programs of study emphasizing management of construction, materials, construction combined with structural analysis and design, or other work best suited to their requirements.

In construction management, for example, a suggested program would include ADVANCED JOB MANAGEMENT, CONSTRUCTION MANAGEMENT SEMINAR, CONSTRUCTION ANALYSIS SEMINAR, ADVANCED MATERIALS, CONCRETE, CONSTRUCTION MATERIALS

SEMINAR, and selected subjects in accounting, economics, operations analysis, labor relations, and personnel administration, in addition to the thesis. A suggested program of study emphasizing materials would include CONCRETE, CEMENTITIOUS MATERIALS, MECHANICAL BEHAVIOR OF PLASTICS, COMPOSITE MATERIALS, RESEARCH IN ORGANIC MATERIALS, CONSTRUCTION MATERIALS SEMINAR, and selected subjects in metals, ceramics, elasticity and plasticity, in addition to the thesis. A suggested course of study in construction and structures would include ADVANCED JOB MANAGEMENT, CONSTRUCTION MANAGEMENT SEMINAR, ADVANCED MATERIALS, CONCRETE, and selected subjects in structural mechanics, statically indeterminate structures, structural design, elasticity, and soil mechanics, in addition to the thesis. All of these are subject to variation to meet the needs of the individual student.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

In addition to the general requirements set forth in Section 3 of this Catalogue, applicants must present evidence of sufficient undergraduate training to prepare them for the advanced subjects which they wish to take. This training generally will include the following subjects:

Two terms of applied mechanics.
One term of materials.
Two terms of structural analysis and design, including consideration of statically indeterminate structural types.

In special instances, suitable professional experience may be accepted in lieu of formal training in certain of the above subjects. Students whose undergraduate training has been in other areas, such as architecture or business administration, may substitute for the above subjects others which are well suited to provide a foundation for advanced study in construction, management, materials, and related fields. Otherwise, the student may make up prerequisites during attendance as a graduate student.

MASTER OF SCIENCE IN BUILDING ENGINEERING AND CONSTRUCTION

Subject to Department approval, up to 24 units of the more advanced undergraduate subjects may be accepted in partial fulfillment of the requirements for the degree of Master of Science.

BUILDING ENGINEER

Programs of study leading to the degree of Building Engineer provide opportunities for a broader training than that required for the Master's degree and better preparation for professional practice in building engineering and construction, and in management. The rigor of the program and the quality of academic performance required are substantially those demanded of students working toward the Master's degree. The normal period of study is two full years beyond the Bachelor's degree.

As is noted below, students wishing to undertake graduate work leading to the degree of Materials Engineer may do so under the sponsorship of the Department of Civil Engineering, including Building Engineering and Construction.

MATERIALS ENGINEER AND DOCTOR OF SCIENCE IN MATERIALS ENGINEERING

Students whose primary interest is in the materials of construction and who wish to specialize in materials engineering may pursue programs leading to one of two degrees: Materials Engineer or Doctor of Science in Materials Engineering. They may elect one of these programs after they have completed requirements for the Master of Science in Civil Engineering or in Building Engineering and Construction. Alternatively, they may work concurrently toward one of these Master of Science degrees and toward a degree in materials engineering.

Programs of study leading to graduate degrees in materials engineering will involve, in addition to subjects offered within the Department, a substantial number of subjects in such fields as chemistry, physics, metallurgy, and mechanical engineering. For specific programs the student should consult his Graduate Registration Officer.

Department of Electrical Engineering

PETER ELIAS, PH.D.
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Professor of Electrical Engineering; Dean of the Graduate School

MURRAY FRANK GARDNER, S.M.
Professor of Electrical Engineering

ERNST ADOLPH GUILLEMIN, PH.D.
Edwin Sibley Webster Professor of Electrical Engineering

GORDON STANLEY BROWN, SC.D., D.ENG.
Professor of Electrical Engineering; Dean of the School of Engineering

ARTHUR ROBERT VON HIPPEL, PH.D.
Professor of Electrophysics

HAROLD EUGENE EDGERTON, SC.D., D.ENG.
Professor of Electrical Measurements

JEROME BERT WIESNER, PH.D. (*Absent*)
Professor of Electrical Engineering

WILLIAM HENRY RADFORD, D.ENG.
Professor of Electrical Communications; Associate Director of Lincoln Laboratory

LAN JEN CHU, SC.D.
Professor of Electrical Engineering

JOHN GEORGE TRUMP, SC.D.
Professor of Electrical Engineering

RICHARD HENRY BOLT, PH.D. (*Absent*)
Professor of Acoustics

KARL LELAND WILDES, S.M.
Professor of Electrical Engineering, Emeritus; Lecturer

HENRY JOSEPH ZIMMERMANN, S.M.
Professor of Electrical Engineering; Director of the Research Laboratory of Electronics

CLAUDE ELWOOD SHANNON, PH.D.
Donner Professor of Science

ROBERT MARIO FANO, SC.D. (*at Lincoln Laboratory*)
Professor of Electrical Communications

WALTER ALTER ROSENBLITH, ING.RAD.
Professor of Communications Biophysics

DAVID CALVIN WHITE, PH.D.
Professor of Electrical Engineering

RICHARD BROOKS ADLER, SC.D.
Professor of Electrical Engineering

SAMUEL JEFFERSON MASON, SC.D.
Professor of Electrical Engineering

TRUMAN STRETCHER GRAY, SC.D.
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YUK-WING LEE, SC.D.
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LOUIS DIJOUR SMULLIN, S.M.
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RICHARD HENRY FRAZIER, S.M.
Professor of Electromechanics

EDWARD FORREST MOORE, PH.D.
Professor of Electrical Engineering (Visiting)

JOHN FRANCIS REINTJES, M.E.E.
Professor of Electrical Engineering

MAURICE BOISVERT, SC.D.
Professor of Electrical Engineering (Visiting)

PARRY MOON, S.M.
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ROBERT LOUIS KYHL, PH.D.
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Associate Professor of Electrical Engineering

DEAN NORMAN ARDEN, PH.D.
Associate Professor of Electrical Engineering

MARCY EAGER, S.B.
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LEONARD ABRAHAM GOULD, SC.D.
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ALAN HILDRETH BARRETT, PH.D.
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AMAR GOPAL BOSE, SC.D.
Associate Professor of Electrical Engineering

MOISE HERBERT GOLDSTEIN, JR., SC.D.
Associate Professor of Electrical Engineering

JOHN MCCARTHY, PH.D.
Associate Professor of Communications Sciences

RICHARD DOUGLAS THORNTON, SC.D.
Associate Professor of Electrical Engineering

EIICHI GOTO
Associate Professor of Electrical Engineering (Visiting)

ELIE JOSEPH BAGHDADY, SC.D.
Assistant Professor of Electrical Engineering

EDWARD ARTHURS, SC.D.
Assistant Professor of Electrical Engineering

PERRY AMBROSE MILES, PH.D.
Assistant Professor of Electrical Engineering

RONALD ARTHUR HOWARD, SC.D.
Assistant Professor of Electrical Engineering

WILLIAM DAVID JACKSON, PH.D.
Assistant Professor of Electrical Engineering

DAVID REMPFER WHITEHOUSE, SC.D.
Assistant Professor of Electrical Engineering

ARTHUR CLARKE SMITH, PH.D.
Assistant Professor of Electrical Engineering

HERBERT MARTIN TEAGER, SC.D.
Assistant Professor of Electrical Engineering

ABRAHAM BERS, SC.D.
Assistant Professor of Electrical Communications

JACK BONNELL DENNIS, SC.D.
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JAMES WILLIAM GRAHAM, S.M.
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EDWARD MAX HOFSTETTER, SC.D.
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IRWIN MARK JACOBS, SC.D.
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ROBERT EVEREST NEWNHAM, PH.D.
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WILLIAM TOWER PEAKE, SC.D.
Assistant Professor of Electrical Engineering

THOMAS GREENWAY STOCKHAM, JR., SC.D.
Assistant Professor of Electrical Communications

JOHN BLAIR, SC.D.
Assistant Professor of Electrical Engineering

ROBERT GRAY GALLAGER, SC.D.
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JAMES GOE GOTTLING, SC.D.
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BARNEY REIFFEN, PH.D.
Assistant Professor of Electrical Engineering (Visiting)

AHMED H. EL-ABIAD, PH.D.
Assistant Professor of Electrical Engineering (Visiting)

SHELDON GRUBER, SC.D.
Assistant Professor of Electrical Engineering

FREDERICK CLAIR HENNIE, III, SC.D.
Assistant Professor of Electrical Engineering

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MARTIN SCHETZEN, SC.D.
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HARRY LESLIE VAN TREES, JR., SC.D.
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LEO LEROY BERANEK, SC.D.
GODFREY THOMAS COATE, M.S.
ALEXANDER KUSKO, SC.D.
MORTON LOEWENTHAL, PH.D.
GEORGE STROKE, DR.ES.SC.

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FREDERICK JELINEK, S.M.
WAYNE GEORGE KELLNER, S.M.
BERNARD WENTZELL LOVELL, S.M.
TRENCHARD MORE, JR., S.M.
WALTER CARLTON SCHWAB, S.M.
ROBERT SHANKLIN COOPER, M.S.E.E.
ALVIN WILLIAM DRAKE, E.E.
RICHARD YERKES KAIN, S.M.
ROBERT SPAYDE KENNEDY, S.M.
HARRY BARNEY LEE, JR., S.M.
JAMES DONALD BRUCE, S.M.
BRUCE DANIELS WEDLOCK, S.M.
RALPH ALTER
RICHARD JULIAN BRIGGS, S.M.
THOMAS HERNE CRYSTAL, S.M.
JOHN RODGERS CUMMINGS, E.E.
WARD DOUGLAS GETTY, M.S.E.
JOSEPH LINDLEY HALL, II, S.M.
JOHN MICHAEL HEINZ, E.E.
THOMAS KAILATH, SC.D.
THOMAS GARDINER KINCAID, S.M.
GERALD BURT KLIMAN, S.M.
JOHN DAVID RENTSCHLER KRAMER, JR., S.M.
JASWANT GANUGAPATI KRISHNAYYA, E.E.
EMANUEL LANDSMAN, S.M.
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JOHN SPENCER MacDONALD, S.M.
JAMES RUSSELL MELCHER, M.S.
ALAN VICTOR OPPENHEIM, S.M.
RICHARD JOHN SCHWARTZ, S.M.
ALWYN CHARLES SCOTT, S.M.
OLEH JOHN TRETIAK, S.M.
DONALD EUGENE TROXEL, S.M.
WILLIAM SOULE WIDNALL, S.B.

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Assistant to the Head of the Department
FREDERICK HENRY FAIRCHILD, B.S.

Non-Resident Instructors

GEORGE LEE BALDWIN, D.SC.
WILLIAM JOSEPH CADDEN, PH.D.
CHARLES A. CHURCH, JR., M.S.
ERNEST OSCAR CODIER, M.S.
DONALD I. FRUSH, B.S.
JAMES FREDERICK KAISER, SC.D.
HAROLD WILLIAM KATZ, PH.D.
JAMES H. MORRISSEY, M.A.
CABELL NICHOLAS PRYOR, JR., S.M.
LEONARD RABINS, M.S.E.E.
JOHN PARKER RUNYON, DIPL.MATH.
FRANK DAIR SKINNER, SC.D.
MAURICE HOWARD SLUD, A.M.
EDWARD PALMER STABLER, M.S.
GEORGE NORMAN TRYTTEN, M.S.

Research Associates

ARTHUR ALBERT, PH.D.
JOHN SUTTON BARLOW, M.D.
MANUEL VALDIVIA CERRILLO, PH.D.
KENNETH JOSEPH GERMESHAUSEN, S.B.
OSCAR JAN GROSCH, M.SC.
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NELLO MARIO ONESTO, DOTT.MAT.
DEAN ARNOLD POWERS, E.E.
MAGNUS INGVALD SMEDAL, M.D.
FRANCIS LEE WEILLE, M.D.

Professors Emeriti

RALPH RESTIEAUX LAWRENCE, S.B.
Professor of Electrical Machinery, Emeritus
HERBERT BRISTOL DWIGHT, D.SC.
Professor of Electrical Machinery, Emeritus
RALPH GORTON HUDSON, S.B.
Professor of Electrical Engineering, Emeritus
KARL LELAND WILDES, S.M.
Professor of Electrical Engineering, Emeritus; Lecturer
RICHARD DUDLEY FAY, A.B., S.B.
Associate Professor of Electrical Communications, Emeritus
LYMAN MINER DAWES, S.B.
Assistant Professor of Industrial Applications, Emeritus

ELECTRICAL ENGINEERING

Starting from a relatively modest beginning about one hundred years ago, the field of electrical engineering has become one of great variety and scope. Today its products and services influence the daily living of most of the world's population, and the tempo of growth and change continues. Because new concepts and developments are steadily appearing in the field, professional study and training must give more than a competence to handle the problems of the present. Students should not merely seek to acquire specific skills and methods; they must search for deep understanding of their work and direct it toward the future.

Electrical engineering at M.I.T. supports, in the main, two impelling desires of man. The first is his desire to establish communication — between man and man, between man and machine, and between machine and machine. Radar, radio and wire telephony, measurement, electronics, computation, and control — which are broadly referred to as *processing and transmitting information* — are the fields in which this communication takes place. The second is man's desire to substitute machines for human muscle — the giant motors, machines, and power systems that control the wheels of industry and also give us heat and light. Here the issue is to exploit energy for energy's sake, and we refer to these activities as *processing, transmitting, and controlling energy.*

A vital element in the virility of the environment is the influence of research on the evolution of the academic program. The Department supports large-scale research laboratories in a number of important fields, each with its own shops and supporting staff. These activities greatly enrich the whole academic environment, undergraduate and graduate.

THE UNDERGRADUATE CURRICULA

The Department offers two undergraduate degree programs: Electrical Engineering, a four-year program leading to the Bachelor of Science degree; and Electrical Science and Engineering, which emphasizes a broad and deep mastery of the engineering sciences. For either program cooperative work may be taken (Course VI-A) which interweaves industrial or research experience with education. Course VI-A and Course VI, Program 2, may extend over four or five years depending upon whether the student completes the requirements for the Bachelor of Science degree or goes on for the Master of Science degree.

The common objective of all these programs is to enable the student to develop an enduring basis upon which he can establish a career — not merely a job — in the multitude of professional, industrial, or business areas which depend upon electrical technology. In preparation for his career, the electrical engineering student must develop a working mastery of the basic sciences of mathematics, physics, and chemistry, with emphasis on mechanics, electricity and magnetism, and thermodynamics. On these are built his professional study of the principles of electrical engineering and their applications.

A major feature of the professional programs of the last three years is the group core of seven classroom subjects, embracing the areas of circuit theory, electronic devices, circuits and signals, field theory, energy processing, and materials, which are required for all students in the Department. In the classroom, emphasis is placed first on basic principles and methods of analysis and then on their integration and application to a broad range of specific electrical processes and equipment. The student becomes aware that these principles and applications form a closely integrated core of electrical science. By applying basic principles in elective subjects and in his thesis research in the fourth year, each student achieves a still deeper understanding of the significance of the sciences for his field.

The laboratory subjects are used to teach experimental technique and not to illustrate the classroom material. Illustration is provided by classroom demonstrations. The laboratory objectives go beyond the mastery of related experimental facts, methods, and techniques. The work includes a large proportion of project activity, in which students acquire the art of providing an experimental model of a physical situation and using it to achieve the objectives of an engineering investigation. Here each student encounters the need for engineering judgment, team work, and careful planning. He sharpens his ability to observe, gains confidence in making decisions from independent, creative thought, and assumes a progressively increased responsibility for the planning and execution of his laboratory work.

Many features of the programs contribute strongly to the development of initiative, judgment, resourcefulness, and responsibility. Indi-

vidual study, under staff guidance, is encouraged. Close association among staff and students in small class sections serves to encourage vigorous and healthy discussions among students and staff who have similar interests.

Electrical Engineering (Course VI)

THE ELECTRICAL ENGINEERING PROGRAM

The Course leads to the degree of Bachelor of Science in Electrical Engineering. This four-year program is designed for the student who wishes to defer the decision on his future work or on graduate study until toward the end of his program. In addition to the humanities electives, about one-half of the senior-year program is elective. The student's selection of subjects, made in consultation with his Faculty Counselor, will depend on whether he expects to undertake graduate study in electrical engineering or some other field, at M.I.T. or elsewhere, or expects to enter industry for work or further study in an industrial training program; a total of 16 units of additional humanities may be elected.

The curriculum requirements for the Electrical Engineering Program are given below.

1. ELECTRICAL ENGINEERING PROGRAM CURRICULUM

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)			176
	PHYSICS 8.031 and 8.041[1] are prescribed. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.		
DEPARTMENTAL PROGRAM			
	Required subjects		
6.01	INTRODUCTORY CIRCUIT THEORY I	4 0 8	
6.02	INTRODUCTORY CIRCUIT THEORY II	4 0 8	
6.03T	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8	
6.05	ELECTRONIC CIRCUITS AND SIGNALS	4 0 8	
6.06T	FIELDS, FORCES, AND MOTION	3 0 6	
6.07T	ENERGY TRANSMISSION AND RADIATION	3 0 6	
6.08T	MOLECULAR ENGINEERING	3 0 6	
6.70	EXPERIMENTAL ELECTRONICS	1 4 1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1 4 1	
6.72	ELECTROMAGNETIC LABORATORY	1 4 1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY	6*	
2.02	MECHANICS OF SOLIDS II	3 0 5	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4 0 5	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3 0 6	
	THESIS	9	
			134
	Elective subjects		
	Unspecified		50
Total units required for the S.B. degree			360

[1] 8.041 must be followed by 8.051 (or 8.05).
* 6.73 is a "time arranged" subject. A minimum of six units is required by the department.

THE ELECTRICAL SCIENCE AND ENGINEERING PROGRAM

This program is offered for a selected group of students who feel relatively confident at the sophomore level that they will want to go on to graduate study and therefore wish an early opportunity to build a basic background in the engineering sciences. There is abundant evidence pointing to the need for graduate study to equip a young engineer with first-rate technical competence and breadth in the world of today and tomorrow. This program is distinguished from Program 1 by the extent to which its curriculum includes higher mathematics and physics and emphasizes the electrical science aspects of the core curriculum subjects.

Students normally apply for admission to Program 2 at the beginning of the sophomore year. Transfer students or others who are well prepared in mathematics and who have completed the work of the sophomore Program 1 curriculum may be admitted at the beginning of the junior year. It is expected that students who elect Program 2 will maintain high academic records and that many will wish to continue their education to the level of the doctorate. The Department urges all students in the program to spend at least one and preferably two summers gaining practical experience in some industrial activity before graduation. Faculty Counselors will assist them with this.

Program 2 may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

2. ELECTRICAL SCIENCE AND ENGINEERING PROGRAM CURRICULUM

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)			176
	PHYSICS 8.031 and 8.041[1] are prescribed. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.		
DEPARTMENTAL PROGRAM			
	Required subjects		
6.013	INTRODUCTORY ELECTRIC CIRCUIT THEORY	4 0 8	
6.023T	ELECTRONIC DEVICES AND CIRCUITS	4 0 8	
6.033T	ELECTROMAGNETIC FIELDS AND ENERGY	4 0 8	
6.053T	ELECTRONIC CIRCUITS AND SIGNALS	4 0 8	
6.063T	FIELDS, FORCES, AND MOTION	3 0 6	
6.073T	ENERGY TRANSMISSION AND RADIATION	3 0 6	
6.083T	MOLECULAR ENGINEERING	3 0 6	

6.11	[2]PROJECT SEMINAR	2	0	4	
6.12	[2]PROJECT SEMINAR	2	0	4	
6.13	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	3	0	6	
6.70	EXPERIMENTAL ELECTRONICS	1	4	1	
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
6.72	ELECTROMAGNETIC LABORATORY	1	4	1	
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY			6*	
2.02	MECHANICS OF SOLIDS II	3	0	5	
8.05	PHYSICS OF ATOMS AND MOLECULES I	4	0	8	
8.06	PHYSICS OF ATOMS AND MOLECULES II	4	0	8	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
18.18	PROBABILITY	3	0	6	
					170
	Elective subjects				
	Unspecified				16
Total units required for the S.B. degree					362

[1] 8.041 must be followed by 8.051 (or 8.05).
[2] 6.11 and 6.12 PROJECT SEMINAR satisfy the S.B. thesis requirement.
* 6.73 is a "time arranged" subject. A minimum of 6 units is required by the department.

Electrical Engineering (Cooperative Course) (Course VI-A)

This program combines academic study with industrial practice correlating the scientific and engineering principles of the classroom and laboratory with from thirty to sixty weeks of practical experience in the plants of a particular industry. This educational plan makes it possible for students to do some "undergraduate" work in industry interleaved with their undergraduate studies at the Institute. The first four years of the required studies are identical in academic content with those of Course VI. The fifth year includes a complete academic year of graduate work, subject to the provisions of the Graduate School.

Candidates for admission to the Course are selected from the second-year class at the Institute and from transfer students who have completed substantially the equivalent of the first two years of Course VI. The fifth year necessitates admission to the Graduate School, for which acceptance is based on each student's scholastic record and upon personal qualifications, as exhibited in his cooperative work experience.

Taken together, the fields of work and the application of the cooperating companies cover substantially the entire spectrum of electrical technology and the electrical industry. While a student is normally associated only with one company for his plant work, his plant assignments are arranged to provide broad experience with the affairs and operating procedures of industry and with the kinds of work in which engineers are engaged. The level of technical sophistication and responsibility at the plants is kept in step with each student's growing technical competence as he advances in his academic program.

The manufacturing companies — such as the General Electric Company, International Business Machines Corporation, the Raytheon Company, General Radio Company, and Philco Corporation — provide experience in production and manufacturing, testing, design, development, and research in various areas of the electronics, power, communications, control, and computation fields. The utility companies — including the American Electric Power Corporation and the Boston Edison Company — provide experience related to the technical operation, system planning, administration, and supporting research of a large electric utility system. The Bell Telephone Laboratories afford the opportunity for industrial practice in the development of communication apparatus, circuits, and equipment for the Bell Telephone System. The government service laboratories, such as the Naval Ordnance Laboratory and the Air Force Cambridge Research Center, provide opportunities for students to learn about and to experience, with progressively increased responsibility, the many skills and technical disciplines which are brought together in a large laboratory that is concerned with basic and applied research and creative engineering covering a wide range of electrical technology.

Students in training at the plants are subject to the usual company regulations. They receive regular compensation for their work. During the practice periods, classes in prescribed academic subjects are held two evenings a week. At the conclusion of the work, students are not obligated to accept employment with the company, nor is the company obligated to offer employment.

The Course leads to the degree of Bachelor of Science in Electrical Engineering for four years of study; and may lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously[1] at the end of the graduate year, if the student is admitted to the Graduate School. The curriculum requirements for the Bachelor of Science degree are given below.

[1] In this case, a total of 4 terms of industrial practice and industrial project subjects is required.

CURRICULUM BASED ON ELECTRICAL ENGINEERING (COURSE VI, PROGRAM 1)

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)				**176**
	PHYSICS 8.031 and 8.041[1] are prescribed. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.			
DEPARTMENTAL PROGRAM				
	Required subjects			
6.01	INTRODUCTORY CIRCUIT THEORY I	4	0	8
6.02	INTRODUCTORY CIRCUIT THEORY II	4	0	8
6.03T	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.05	ELECTRONIC CIRCUITS AND SIGNALS	4	0	8
6.06T	FIELDS, FORCES, AND MOTION	3	0	6
6.07T	ENERGY TRANSMISSION AND RADIATION	3	0	6
6.08T	MOLECULAR ENGINEERING	3	0	6
6.70	EXPERIMENTAL ELECTRONICS	1	4	1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
6.72	ELECTROMAGNETIC LABORATORY	1	4	1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY		6*	
2.02	MECHANICS OF SOLIDS II	3	0	5
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6
	THESIS[2]		9	
				134
	Elective subjects			
	Unspecified[2,3]			**50**
Total units required for the S.B. degree				**360**

[1] 8.041 must be followed by 8.051 (or 8.05).
[2] Students who go on for the S.M. degree and receive the S.B. and S.M. degrees simultaneously may substitute 9 units of additional elective for the S.B. thesis.
[3] Industrial practice subjects must be taken by students in this Course VI-A curriculum; elective credit for these subjects is limited to a maximum of 27 units and a minimum of 18 units.
* 6.73 is a "time arranged" subject. A minimum of six units is required by the department.

CURRICULUM BASED ON ELECTRICAL SCIENCE AND ENGINEERING (COURSE VI, PROGRAM 2)

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)				**176**
	PHYSICS 8.031 and 8.041[1] are prescribed. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.			
DEPARTMENTAL PROGRAM				
	Required subjects			
6.013	INTRODUCTORY ELECTRIC CIRCUIT THEORY	4	0	8
6.023T	ELECTRONIC DEVICES AND CIRCUITS	4	0	8
6.033T	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.053T	ELECTRONIC CIRCUITS AND SIGNALS	4	0	8
6.063T	FIELDS, FORCES, AND MOTION	3	0	6
6.073T	ENERGY TRANSMISSION AND RADIATION	3	0	6
6.083T	MOLECULAR ENGINEERING	3	0	6
6.13	ELECTRIC AND MAGNETIC PROPERTIES OF MATTER	3	0	6
6.70	EXPERIMENTAL ELECTRONICS	1	4	1
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
6.72	ELECTROMAGNETIC LABORATORY	1	4	1
6.73	ADVANCED ELECTRICAL ENGINEERING LABORATORY		6*	
2.02	MECHANICS OF SOLIDS II	3	0	5
8.05	PHYSICS OF ATOMS AND MOLECULES I	4	0	8
8.06	PHYSICS OF ATOMS AND MOLECULES II	4	0	8
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6
18.18	PROBABILITY	3	0	6
	[2]*Industrial project subject*		9	
				167
	Elective subjects			
	[2]*Unspecified*			**18**
Total units required for the S.B. degree				**361**

[1] 8.041 must be followed by 8.051 (or 8.05).
[2] Industrial practice and industrial project subjects must be taken by students in this Course VI-A curriculum; credit for these subjects is limited to a maximum of 27 units and a minimum of 18 units.
*6.73 is a "time arranged" subject. A minimum of six units is required by the department.

GRADUATE STUDY IN ELECTRICAL ENGINEERING

Graduate work in the Department of Electrical Engineering is in the fullest sense a partnership with an eminent professional faculty. Its objective is to aid each graduate student to develop a deeper grasp of fundamental principles and to achieve skill in their creative application to new and unsolved problems. The work is built around the close interrelations among mathematics, physics, advanced electrical engineering, and an extensive and diversified group of research and teaching activities.

Three kinds of advanced degree programs are offered. The program for the degree of Master of Science in Electrical Engineering provides one year of graduate work in which scientific and engineering principles are strengthened and applied in a limited area of electrical engineering. The programs for the degree of Electrical Engineer or for the degree of Materials Engineer require a much broader two-year graduate program for students preparing for engineering practice. The three-year program for the degree of Doctor of Science or Doctor of Philosophy includes about one year of intensive research and leads toward careers in teaching or research. These one-, two-, and three-year periods are full-time minima for qualified Bachelors in Electrical Engineering.

There are no fixed programs of study for these degrees. Particular effort is made with each student to develop his program of graduate study along the lines of his individual special interest. Such a procedure provides him with a strong incentive for a high level of accomplishment and gives him a specialized ability that is immediately useful. This specialized ability,

however, is deemed a less significant result of graduate study than is the clearer insight into and better integration of fundamental principles so generally gained by the graduate student. Soundly conceived advanced work rarely fails to send the student back to deepen his understanding of elementary but basic principles. These ideas are evidenced by the methods of approach used in graduate engineering subjects and by the fact that students usually include in their programs further formal study of mathematics and physics.

Graduate work usually centers about a number of especially vital areas in electrical engineering. Each of these areas is characterized by an active research program coordinated with the graduate class and laboratory programs. Representative fields in which there are graduate subjects appropriate for advanced degree work in electrical engineering include:

Passive network analysis and synthesis
Active network theory
Electronic circuits and systems
Communications theory and systems
Transient analysis
Electronic instrumentation
Switching circuits
Transistors and other solid-state control devices
Molecular engineering
Computation processes and systems
Systems engineering and operations research
Feedback and process control systems
Nonlinear system analysis
Statistical communication theory
Information theory
Noise and modulation theory
Microwave circuits and tubes
Applied field theory
Antennas
Energy conversion devices and systems
Engineering acoustics
Hearing, speech and language
Electro-neurophysiology
High-voltage radiation engineering

In addition, many subjects in physics and mathematics are appropriate to electrical engineering; work is also available in business and industrial management, economics, and social science.

Research laboratories of extraordinary range and strength are sponsored by the Department. The principle of close integration between regular graduate studies and these research laboratories has proven very effective, yielding educational values beyond those of formal study alone. Most of the research work is free from security restrictions, and graduate student participation is a significant element of many projects. The Department regards active research as a dominant influence in its graduate program, and each project is conceived and administered so that graduate students can and do have full opportunity to associate with it while retaining their scientific individuality and initiative. Some of the research projects are mentioned in the following paragraphs.

In *servomechanisms and control*, a large research and development program is closely coupled with extended graduate study covering numerous and varied phases of this subject. Close integration of control, digital and analog computation, and instrumentation, involving solid-state devices, electronic and electric circuits, and electromechanical, hydraulic, and mechanical elements in varied dynamical systems and processes, provides excellent educational breadth and depth in a currently active field.

In the *Research Laboratory of Electronics*, sponsored jointly by the Departments of Electrical Engineering and Physics, particular attention is currently given to microwave electronics and its applications in modern communication systems and devices, network theory and network synthesis, the generation of high-energy radiation, electronic computation, microwave gaseous discharges and their role in providing high-density plasmas, atomic beams in relation to the development of time standards and the determination of electric and magnetic moments, processing and transmitting information, language translation, switching logic, statistical theory of communication, transistor circuitry and applications, and communications biophysics.

In *energy conversion and control*, a group is concerned with understanding, developing, and controlling processes by which energy is converted between electrical and other forms — specifically, energy conversion utilizing the interaction of electromagnetic energy and semiconductor materials, electromechanical energy conversion utilizing both magnetohydromagnetic principles and the physics of interaction between moving material bodies and electromagnetic fields, heat transfer in electrical conversion devices, dynamics of and analog representations for generating and regulating portions of electrical systems for air vehicles, analysis of nonlinear continuous and pulsed-data-type systems, and the analysis of magnetic and semiconductor power-type control devices.

In *computer components and systems*, a group is concerned with basic research in computer design and application. Digital computer components involving transistors, ferrites, and other

new materials are being devised. One group is developing a computer component called a "cryotron," whose valve action utilizes control of superconductivity by a magnetic field at temperatures near absolute zero. Microminiaturization via evaporative-film techniques are becoming increasingly effective in component development. Of interest also are general mathematical techniques such as linear system analysis, probability theory, linear programming, and Monte Carlo methods, which lead to formulations requiring large-scale digital computation. These activities coordinate with the *M.I.T. Computation Center*, which has as its objective the encouragement and training of students, engineers, and scientists in the use of modern computing machines in their research efforts.

A group in *high voltage research* is concerned with the techniques of producing high-energy particles and radiation, and with their application to the needs of science, medicine, and industry.

In the *Laboratory for Insulation Research* a new approach to the synthesis of engineering materials, termed "molecular engineering," is being pioneered. Of current interest are investigations of the behavior of matter at high electric field strengths; the magnetic behavior of matter at microwave frequencies; the study of the formation and behavior of ferroelectric domains and their dependence on electric field, temperature, and pressure and frequency; and the potentialities and limitations of ferromagnetic semiconductors.

In *acoustics*, research deals with sound waves from sub-audible to high-ultrasonic frequencies in solids, liquids, and gases, covering a wide range of topics relevant to communications, speech synthesis, physical acoustics, and techniques for the use of sound and ultrasound in engineering and science.

A facility differing in kind from these laboratories but equally essential in the educational program is the Vail Library, one of three great electrical libraries in the world, which now comprises approximately 50,000 volumes.

From the emphasis given to the graduate student's association with active projects, it is evident that his graduate study is conceived as a coordinated whole, culminating in thesis research, which allows him to develop his ability to do constructive reasoning and to contribute to the advancement of engineering.

Studies toward an advanced degree can be pursued either as a full-time student or in combination with a graduate assistantship, of which about sixty are offered each year beginning in the summer or in the fall. These assistantships provide the opportunity for participation in one of the sponsored research laboratories associated with the Electrical Engineering Department, or participation in the teaching program of the Department, or both. All assistantships in the Department of Electrical Engineering are full time and permit carrying about 50 per cent of a full-time graduate study program. Thus, a degree requires about twice the minimum time, but holders of the appointments find the additional educational experience associated with them quite as valuable as the formal study. For the doctorate especially, candidates often desire both teaching and research experience. The financial assistance given by these appointments is frequently an important additional consideration.

A brochure on *Graduate Study, Teaching, and Research in Electrical Engineering*, describing research and teaching opportunities in detail, may be obtained from the Department.

Entrance Requirements for Graduate Study

The general requirements are as set forth in Section 3 of this Catalogue, without exception.

The Graduate Record Examination, described on page 62, is required of all United States applicants to graduate-degree programs in electrical engineering. Applications which, because of unusual circumstances, do not contain the report on this examination will be considered with the understanding that the examination will be taken and reported to M.I.T. at the first possible opportunity. In addition to the general requirements for all graduate students, a candidate for an advanced degree in electrical engineering must present evidence of training in most professional areas considered essential for further study in electrical science and engineering. These areas are indicated approximately by the following Institute subjects:

MECHANICS OF SOLIDS II (2.02)
HEAT ENGINEERING (2.40)
or
INTRODUCTION TO QUANTUM PHYSICS (8.051)
or
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)
INTRODUCTORY CIRCUIT THEORY (6.01, 6.02)
ELECTROMAGNETIC FIELDS AND ENERGY (6.03T)
ELECTRONIC CIRCUITS AND SIGNALS (6.05)
FIELDS, FORCES, AND MOTION (6.06T)
ENERGY TRANSMISSION AND RADIATION (6.07T)
ADVANCED CALCULUS FOR ENGINEERS (18.05)

Credit is not usually allowed for undergraduate subjects in which the applicant's grades are low. Superior achievement in undergraduate mathematics and physics is considered particularly important.

Up to a total of 24 units of subjects which are considered prerequisites for graduate studies may be taken as part of a graduate program for credit toward the Master's degree.

The Graduate Degrees

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

The general requirements for the Master's degree are given in Section 3.

Students working for the Master's degree are expected to devote themselves to a few subjects, not more than four each term, in addition to their research. The subjects are wholly elective and are not restricted to those given by the Electrical Engineering Department; however, the program of study must be well balanced, emphasizing one or more of the mathematical, economic, or experimental aspects of electrical engineering.

The Cooperative Course in Electrical Engineering (Course VI-A) and Electrical Science and Engineering (Course VI, Program 2), which are described above, may both lead to the degrees of Bachelor of Science and Master of Science in Electrical Engineering, awarded simultaneously at the end of the graduate year.

ENGINEER DEGREES

Able students who wish to prepare for creative application of engineering and scientific principles in engineering practice and who desire more extensive training than is possible within the 96 units required for the Master's degree, yet who are not interested in acquiring the training in research afforded by doctoral study, are encouraged to study for the Electrical Engineer or Materials Engineer degrees. Programs for these degrees are elective except for the thesis and ordinarily require at least four terms of graduate study beyond the Bachelor's degree level.

The general requirements for the Engineer degrees are given in Section 3.

DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY

Only students who have shown promise of performing truly creative work in either engineering or engineering science are encouraged to study for the Doctor's degree. Students entering on graduate work who do not have records that show strong evidence of this ability are usually advised to qualify first for the Master's degree. The thesis research for the doctorate is expected to make a substantial and noteworthy contribution in electrical engineering or a related field.

The general requirements for the Doctor's degree are given in Section 3.

The General Examination is divided into two parts, of which the first is both written and oral. This first part, which should be taken within one year after beginning graduate study, is designed to determine whether the candidate is qualified, in terms of command of the basic sciences and practices of electrical engineering, to take advanced study and research of doctoral caliber. The second part of the General Examination is wholly oral and is taken after the problem for the thesis research has been chosen and the related preparatory program of specialized graduate study has been completed.

Each applicant for the doctorate in electrical engineering is required to demonstrate his ability to read scientific literature in English and in two other modern languages selected from German, Russian, and French.

The field of the Minor is not prescribed by the Department, but usually mathematics or physics is chosen.

Department of Mechanical Engineering

HORTON GUYFORD STEVER, PH.D., SC.D.
Professor and Head of the Department

JAMES HOLT, S.B.
Professor of Mechanical Engineering; Executive Officer

CHARLES FAYETTE TAYLOR, PH.B., M.E.
Professor of Automotive Engineering, Emeritus; Lecturer

CARL RICHARD SODERBERG, TEKN.D., D.ENG.
Institute Professor, Emeritus; Professor of Mechanical Engineering, Emeritus

JOSEPH HENRY KEENAN, S.B.
Professor of Mechanical Engineering

JACOB PIETER DEN HARTOG, PH.D.
Professor of Mechanical Engineering

JOHN THOMAS RULE, S.B.
Professor of Engineering Graphics

SAMUEL CORNETTE COLLINS, PH.D., SC.D.
Professor of Mechanical Engineering

EGON OROWAN, D.ENG.
George Westinghouse Professor of Mechanical Engineering

ASCHER HERMAN SHAPIRO, SC.D.
Professor of Mechanical Engineering

WILLIAM MacGREGOR MURRAY, SC.D.
Professor of Mechanical Engineering

WARREN MAX ROHSENOW, D.ENG.
Professor of Mechanical Engineering

STEPHEN HARRY CRANDALL, PH.D.
Professor of Mechanical Engineering

NORMAN CHRISTIAN DAHL, SC.D.
Professor of Mechanical Engineering

FRANK AMBROSE McCLINTOCK, PH.D.
Professor of Mechanical Engineering

BRANDON GARNER RIGHTMIRE, SC.D.
Professor of Mechanical Engineering

CARL LOUIS SVENSON, S.M.
Professor of Mechanical Engineering

JAMES ALAN FAY, PH.D. (*Absent*)
Professor of Mechanical Engineering

KENNETH ROBERT WADLEIGH, SC.D.
Professor of Mechanical Engineering; Dean of Student Affairs

AUGUSTUS RUDOLPH ROGOWSKI, S.M.
Associate Professor of Mechanical Engineering

DOUGLAS PAYNE ADAMS, S.B., A.M.
Associate Professor of Engineering Graphics

PRESCOTT ARTHUR SMITH, S.B.
Associate Professor of Mechanical Engineering

AUGUST LUDWIG HESSELSCHWERDT, JR., S.M.
Associate Professor of Mechanical Engineering

STANLEY BACKER, SC.D.
Associate Professor of Mechanical Engineering

MAURICE EDWIN SHANK, SC.D. (*Absent*)
Associate Professor of Mechanical Engineering

TAU-YI TOONG, SC.D.
Associate Professor of Mechanical Engineering

JESSE LOWEN SHEARER, SC.D.
Associate Professor of Mechanical Engineering

ROBERT WELLESLEY MANN, SC.D.
Associate Professor of Mechanical Engineering

NATHAN HENRY COOK, SC.D.
Associate Professor of Mechanical Engineering

GEORGE NICHOLAS HATSOPOULOS, SC.D.
Associate Professor of Mechanical Engineering

SHIH-YING LEE, SC.D.
Associate Professor of Mechanical Engineering

ALAN NEIL STROH, PH.D.
Associate Professor of Mechanical Engineering

HENRY MARTYN PAYNTER, SC.D.
Associate Professor of Mechanical Engineering

PETER GRIFFITH, SC.D.
Associate Professor of Mechanical Engineering

STEVEN ANSON COONS
Associate Professor of Mechanical Engineering

ARTHUR T. MURPHY, PH.D.
Associate Professor of Mechanical Engineering (Visiting)

ERNEST RABINOWICZ, PH.D.
Associate Professor of Mechanical Engineering

JOSEPH KENNETH ROYLE, PH.D.
Associate Professor of Mechanical Engineering (Visiting)

WALTER CARL EBERHARD, S.B.
Assistant Professor of Engineering Graphics, Emeritus; Lecturer

DEANE LENT, A.B.
Assistant Professor of Engineering Drawing

GEORGE ARTHUR BROWN, SC.D.
Assistant Professor of Mechanical Engineering

ALVE JOHN ERICKSON, SC.D.
Assistant Professor of Mechanical Engineering

RICHARD JOSEPH NICKERSON, SC.D.
Assistant Professor of Mechanical Engineering
GEORGE SHERIDAN REICHENBACH, SC.D.
Assistant Professor of Mechanical Engineering
S. WILLIAM GOUSE, JR., SC.D.
Assistant Professor of Mechanical Engineering
DAVID CLIFFORD PRIDMORE-BROWN, PH.D.
Assistant Professor of Mechanical Engineering
JOHN CLARK CHATO, PH.D. (*Absent*)
Assistant Professor of Mechanical Engineering
PHILIP GRAHAM HILL, SC.D.
Assistant Professor of Mechanical Engineering
HERBERT HEATH RICHARDSON, SC.D.
Assistant Professor of Mechanical Engineering
JOSEPH LeCONTE SMITH, JR., SC.D.
Assistant Professor of Mechanical Engineering
THOMAS BROWN SHERIDAN, SC.D.
Assistant Professor of Mechanical Engineering
ALI SUPHI ARGON, SC.D.
Assistant Professor of Mechanical Engineering
EUSTRATIOS NICOLAS CARABATEAS, SC.D.
Assistant Professor of Mechanical Engineering
DWIGHT MAYLON BILLY BAUMANN, SC.D.
Assistant Professor of Mechanical Engineering
ERNESTO ENRIQUE BLANCO, B.M.E.
Assistant Professor of Mechanical Engineering
JEROME CATZ, SC.D.
Assistant Professor of Mechanical Engineering
RAPHAEL MOISSIS, SC.D.
Assistant Professor of Mechanical Engineering
STEVEN IRWIN FREEDMAN, PH.D.
Assistant Professor of Mechanical Engineering
DEAN CHARLES KARNOPP, PH.D.
Assistant Professor of Mechanical Engineering; Ford Postdoctoral Fellow in Engineering
EDWARD FULTON KURTZ, JR., PH.D.
Assistant Professor of Mechanical Engineering; Ford Postdoctoral Fellow in Engineering
WILLIAM CRAIG MOFFATT, SC.D.
Assistant Professor of Mechanical Engineering

Lecturer

HENRY MERRIAM MORGAN, SC.D.

Instructors

FORBES TAYLOR BROWN, MECH.E.
JOHN MITCHELL REYNOLDS, III, S.M.
ARTHUR SHAVIT, MECH.E.
GARDNER DUDLEY SHEPARD, S.M.
GONZALO SAENZ LEON, A.B., M.S.
KARL NEVELLE REID, JR., M.S.
MICHAEL FRANCIS KOSKINEN, S.M.
DANIEL HABER MARCUS, MECH.E.
DAVID EDWARD NEWLAND, M.A.

Technical Instructors

RALPH JOHN BOWLEY
CLARENCE WILLIAM CHRISTIANSEN
FREDERICK HAROLD ANDERSON
JOHN LEACH

Research Associates

JOHN FRANCIS BLACKBURN, PH.D. (*Absent*)
TSU-NIEN CHIN
WAJURO ITANI, D.ENG.

Professors Emeriti

CHARLES EDWARD FULLER, S.B.
Professor of Theoretical and Applied Mechanics, Emeritus
CHARLES WILLIAM BERRY, S.B.
Professor of Heat Engineering, Emeritus
JOSEPH CAINS RILEY, S.B.
Professor of Heat Engineering, Emeritus
CHARLES FAYETTE TAYLOR, PH.B., M.E.
Professor of Automotive Engineering, Emeritus; Lecturer
GORDON BALL WILKES, S.B.
Professor of Heat Engineering, Emeritus
EARLE BUCKINGHAM
Professor of Mechanical Engineering, Emeritus
CARL RICHARD SODERBERG, TEKN.D., D.ENG.
Institute Professor, Emeritus; Professor of Mechanical Engineering, Emeritus
THEODORE HOWARD TAFT, S.B.
Associate Professor of Heat Engineering, Emeritus
LAWRENCE SOUTHWICK SMITH, S.B.
Associate Professor of Applied Mechanics, Emeritus
WALTER HERMAN JAMES, S.B.
Associate Professor of Mechanical Engineering, Emeritus
ARTHUR LINDSAY GOODRICH, S.B.
Associate Professor of Drawing and Descriptive Geometry, Emeritus
IRVING HENRY COWDREY, S.B.
Associate Professor of Testing Materials, Emeritus
WALTER CARL EBERHARD, S.B.
Assistant Professor of Engineering Graphics, Emeritus; Lecturer

MECHANICAL ENGINEERING

As he looks into the future, the mechanical engineer sees as his province all industry and all science as they are applied to man's purposes. He must lead in the development of new sources of power, high-speed transport, missiles, and travel in space.

Undergraduate study in mechanical engineering must be planned with these objectives in mind. It will include such basic science subjects as the dynamics of solids and fluids, the physics and mechanics of solids, thermodynamics, electrical circuit theory, and electromagnetic field theory.

In addition to these basic studies, the Mechanical Engineering Department is concerned with bridging the gap between science and basic knowledge on the one hand, and the thing which is to be designed or devised on the other. This is the art of engineering, and to teach this art is the primary object of subjects in laboratory and in engineering design. Here each student works under the critical and sympathetic eyes of men skilled in the art. Laboratory experience, which takes many forms, is intended to show how the experimental method is used in the solution of engineering problems. Design experience includes devising means to perform certain specified tasks, such as the design of a device or the synthesis of a system made up of parts having known characteristics. Either experience may culminate in a senior thesis.

The faculty and their students, undergraduate as well as graduate, carry on research and laboratory experiments on a wide range of basic subjects such as thermodynamics, heat transfer, refrigeration and cryogenics, elasticity, plasticity, kinematics and dynamics, fluid and gas dynamics, magnetofluiddynamics, properties of materials, automatic control, design of complex systems, processing of materials, lubrication, and surface phenomena. All these subjects are applied in the design of a great variety of machines and devices.

A field of this width and diversification cannot be learned and mastered in all its details in four college years or even in a lifetime. The objective of our undergraduate program is to provide a broad intellectual horizon for the graduate and to inculcate such habits and skills of study that he will learn new science as it appears and take the initiative in applying it.

THE UNDERGRADUATE PROGRAMS

Mechanical Engineering (Course II)

The work in the first two years of the undergraduate curriculum lays a thorough foundation in mathematics, physics, and chemistry. In the succeeding two years each student has a wide area of choice and may follow his natural interest, restrained only by the necessity of a balanced and logical program, which must have the approval of his Faculty Counselor. While the Faculty Counselor will consider any program a student may propose, the Department has worked out two basic programs, one centered around engineering and the other centered around engineering science. The Course leads to the degree of Bachelor of Science in Mechanical Engineering.

THE ENGINEERING PROGRAM

Building on a base of the pure sciences and the engineering sciences, a student in the Engineering Program has the opportunity to choose a coherent set of subjects in some particular technological area. The object is not specialization but rather a development of skill in joining the scientific with the creative aspects of engineering for useful ends. Examples of such areas are as follows:

Power and Propulsion. Power may be produced by gasoline engines, steam cycles, gas turbines, jets, or as-yet-undeveloped devices like the hydrogen-fusion power plant. The subjects available for this power and propulsion program give each student experience in the scientific approach to the problems which arise in power-producing machines. Since power machinery involves a great many branches of technology, basic analytical methods must be drawn from a variety of disciplines — including thermodynamics, combustion, fluid mechanics, strength of materials, and design — and applied to the analysis and design of engines and power plants.

Design, Manufacturing, and Controls. Design and manufacturing are at the very core of most engineering projects, and many graduate mechanical engineers are engaged in these activities.

The engineering design process starts with a statement of something desired. The engineer creates a concept which tentatively satisfies the requirements of function, environment, and economy. This concept, or a suitable simplification

or model of it, is then subjected to critical analysis in which science, tempered by engineering judgment, is applied at whatever level of sophistication may be justified by the nature of the problem. Since the culmination of the process is a tangible device, the problems of manufacturing must influence the process of design. The manufacture of missiles, rocket engines, nuclear reactors, and other new mechanical devices requires unusual materials which present many challenging problems of fabrication. New tool materials such as ceramics and newly developed machining processes such as spark machining, ultrasonic grinding, and chemical and electrolytic removal processes provide students with interesting research problems that are in the vanguard of engineering progress.

Materials (Including Textiles). Many advances in engineering design and technology are limited by the performance of the materials available for any particular application. To make the most of materials requires a basic understanding of why materials behave mechanically in the way they do and of the measures that may be employed to take advantage of, or to improve upon, their properties for particular applications. In its broadest sense, this task requires a background ranging from the basic sciences of physics, chemistry, and mathematics to the engineering sciences of thermodynamics, mechanics of materials, physical structure of solids, elasticity, and plasticity.

Students may prepare for any of several activities in the general area of materials engineering by an appropriate selection of electives. These activities may range from the engineering aspects of advanced technological developments to the manufacturing, processing, and development of new materials.

Textile technology is a branch of the subject of materials which is growing in importance. It has received special attention within the Mechanical Engineering Department.

The curriculum for the first year is described on pages 38–39; GRAPHICAL CONCEPTS (2.721) is recommended as one of the elective subjects. The undergraduate curriculum is given below. All undergraduate students in mechanical engineering are urged to devote one or two summers to practical experience in some industrial activity of their own choice before graduation.

1. ENGINEERING PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)	PHYSICS 8.03 and 8.04 *or* 8.031 and 8.041[1] must be taken. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.				**176**
DEPARTMENTAL PROGRAM					
	Required subjects				
2.01	MECHANICS OF SOLIDS I	3	0	5	
2.021	DYNAMIC SYSTEMS	3	0	6	
2.03	DYNAMICS	3	0	6	
2.25	FLUID MECHANICS	4	0	8	
2.403	THERMODYNAMICS	4	0	8	
3.14	ENGINEERING MATERIALS	4	2	4	
2.37	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	3	2	5	
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4	
2.731	ENGINEERING DESIGN	3	3	6	
2.671	EXPERIMENTAL ENGINEERING	2	4	2	
2.672	ENGINEERING PROJECTS	2	0	4	
	THESIS		15		
					132
	Elective subjects				
	In specified areas				
2.404	STATISTICAL MECHANICS AND KINETIC THEORY	3	0	6	
	or				
2.414	ENGINEERING THERMODYNAMICS	3	0	6	
	Unspecified		43		
					52
Total units required for the S.B. degree					**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

THE ENGINEERING SCIENCE PROGRAM

Revolutionary advances in science have opened new areas of knowledge whose practical exploitation has only begun. At the same time the pace of technological change has greatly accelerated, so that a man wishing to work at the frontier of engineering development must be prepared both to learn continuously and to make marked shifts in direction several times during his career. All this has created the need for men with a broad training deeply rooted in the sciences.

The program in engineering science prepares students for such careers by study covering two general fields. In the first are physics, chemistry, and mathematics. In the second are the engineering sciences: the dynamics of rigid and elastic bodies, the mechanics of elastic and plastic solids, fluid dynamics, thermodynamics, the dynamics of systems, materials, and electrical science. This program differs from others in the Department because it incorporates more study in mathematics and physics and because the subjects in engineering science are at a level

which builds on the additional mathematics and physics.

Experience in research is an essential part of the Engineering Science Program. Design projects offer experience in the art of engineering. These parts of the program are adjusted to the interests, needs, and capacities of the individual student.

Although it is expected that most students in engineering science will proceed into graduate study, the undergraduate program is designed as a terminal program. It is intended as a basis for a career of versatility in research and development.

The curriculum for the first year is described on pages 38–39; GRAPHICAL CONCEPTS (2.721) is recommended as one of the elective subjects. The undergraduate curriculum is given below. All undergraduate students in mechanical engineering are urged to devote one or two summers to practical experience in some industrial activity of their own choice before graduation.

2. ENGINEERING SCIENCE PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)					176
	PHYSICS 8.031 and 8.041[1] are prescribed. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.				
DEPARTMENTAL PROGRAM					
	Required subjects				
2.01	MECHANICS OF SOLIDS I	3	0	5	
2.021	DYNAMIC SYSTEMS	3	0	6	
2.031	DYNAMICS	4	0	8	
2.271	FLUID DYNAMICS	3	0	6	
2.272	FLUID DYNAMICS	3	0	6	
2.403	THERMODYNAMICS	4	0	8	
2.404	STATISTICAL MECHANICS AND KINETIC THEORY	3	0	6	
3.14	ENGINEERING MATERIALS	4	2	4	
2.39	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	6	
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4	
2.671	EXPERIMENTAL ENGINEERING	2	4	2	
2.672	ENGINEERING PROJECTS	2	0	4	
	THESIS		15		
					146
	Elective subjects				
	In specified areas				
6.01	INTRODUCTORY CIRCUIT THEORY I	4	0	8	
	or				
6.03T	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
	or				
6.14	ELECTRONIC NETWORKS AND DEVICES	4	0	8	
	Unspecified		36		
					48
Total units required for the S.B. degree					370

[1] 8.041 must be followed by 8.051 (or 8.05).

The Advanced Undergraduate Program

In the conviction that a gifted mind can be developed to its full potential when suitably challenged, the Department makes special provision for the education of its exceptional students. Selection of students for the Advanced Undergraduate Program is made at the end of the sophomore year. During their third and fourth years, these men undertake special programs of study designed on an individual basis, with many graduate subjects included. Students in this program have, at the end of the fourth year, an intellectual maturity and a technical knowledge surpassing that of most Master's candidates and are in a unique position to pursue further graduate work. While the emphasis of the program is on the conscious pursuit of excellence rather than on degrees, it is sometimes possible for students in the Advanced Undergraduate Program to acquire the Master's degree before the end of the fifth year.

Students in this program will normally be invited to become members of the Honors Course, described below.

The Undergraduate Honors Course

Towards the end of the junior year an opportunity is offered to a limited additional number to students of superior ability to join an Honors Course group, which provides a coordinated schedule of studies through the senior and a graduate year.

The Honors Course leads to the degrees of Bachelor of Science and Master of Science in Mechanical Engineering, awarded simultaneously at the end of the fifth year of study. The program must satisfy all the requirements for both degrees, including the time allotted to the Bachelor's thesis, with the exception that a single thesis of not less than 30 units is required.

Mechanical Engineering (Cooperative Course) (Course II-B)

The Cooperative Course in Mechanical Engineering gives students the opportunity to acquire a background of industrial experience prior to the professional work of the fourth year. It pro-

vides a period of approximately six months of practical experience, between the end of the sophomore year and the beginning of the senior year, with a selected industrial concern. This is accomplished by rearranging the program of subjects taken in the junior year. The academic program is essentially the same as that of the regular Course in Mechanical Engineering. Except for the period when the student is away from the Institute, he is able to participate in all extracurricular activities with his own classmates.

The activities of the students away from the Institute vary with each company. The principal objective is to give students a background for the environment in which they are likely to work after graduation. The cooperating companies have been invited to participate in this program on the basis of their progressive and sympathetic attitude towards this form of training and the benefit which it provides.

The number of students which can be accommodated is limited, and consequently registration in the Cooperative Course is restricted to students of marked aptitude with clear records in the first two years. Admission to the Course is subject to the approval of the Department and of the cooperating companies. College transfer students may be admitted under equivalent conditions.

Students who are interested in this program should complete application forms not later than January 15 of their sophomore year. A statement indicating preference for location and class group desired should be included. A list of cooperating companies is available at the Headquarters of the Department of Mechanical Engineering.

Representatives of the cooperating companies are invited to interview interested students. They determine, jointly with the Department representative, the distribution of those selected. Students thus chosen become regularly paid employees of the company during the period at the plant and are subject to the usual regulations of that company. They are expected to carry the Course through to completion unless prevented from doing so by exceptional circumstances.

Juniors in the Cooperative Course are also eligible for selection to the Honors Course described above.

CURRICULUM IN THE COOPERATIVE COURSE (COURSE II-B)

The Course leads to the degree of Bachelor of Science in Mechanical Engineering. The curriculum is the same as for Course II, except for the addition of required plant work:

2.951	INDUSTRIAL PRACTICE	40 h.p.w.
2.952	INDUSTRIAL PRACTICE	40 h.p.w.

GRADUATE STUDY IN MECHANICAL ENGINEERING

The Department provides opportunities for graduate work leading to the following degrees: Master of Science in Mechanical Engineering, Master of Science in Textile Technology, Mechanical Engineer, Materials Engineer, Doctor of Science in Mechanical Engineering, and Doctor of Science in Materials Engineering.

In addition to its own extensive facilities for graduate research, the Department cooperates with other departments of the Institute in operating the Engineering Practice School at Oak Ridge, Tennessee. The Practice School is described more fully in Section 1 of this Catalogue.

Entrance Requirements for Graduate Study

The general requirements for admission are those given in Section 3 of this Catalogue.

Students starting 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 will 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, electrical circuits, electromagnetic fields, and materials. In some cases the student will want to strengthen his background by taking some undergraduate subjects in preparation for advanced study; however, he is encouraged to take the most advanced subjects which his abilities and preparation will permit.

The Graduate Degrees

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

The general requirements for the degree are given in Section 3 of this Catalogue.

The student working for the Master of Science in Mechanical Engineering follows a wholly elective program; his subjects are not restricted to those given by the Mechanical Engineering Department. The selection of individual subjects is restricted only by the condition that the program must be substantial and logical in the judgment of the faculty adviser.

The program should be well balanced, emphasizing one or more of the analytical, economic, design, or experimental aspects of mechanical engineering.

MASTER OF SCIENCE IN TEXTILE TECHNOLOGY

Candidates for the Master of Science in Textile Technology should have the training offered by the Institute (or equivalent training from another institution) in the fields of either chemical engineering, chemistry, mechanical engineering, business and engineering administration, or industrial physics. The program for the degree lasts from one to two years, depending upon preparation. Students who have graduated with high standing from technical or textile schools which offer less extensive preparation in science and engineering may be accepted for study, but should expect to spend a minimum of two years to fulfill the degree requirements.

MECHANICAL ENGINEER

In recent years there has developed a need for leaders possessing knowledge in depth in a number of areas associated with mechanical engineering. For those who desire to prepare themselves for engineering practice at a high professional level, the degree of Mechanical Engineer is awarded for a program of study which is more advanced than that for the degree of Master of Science. The requirements for the degree include an additional year of class work beyond the Master's degree together with satisfactory performance in a comprehensive examination. If the Master's degree was not taken at M.I.T., a thesis of 20 to 50 units must be a part of the program. The general requirements for the degree are given in Section 3 of this Catalogue.

MATERIALS ENGINEER

Candidates interested in studying materials engineering in the Mechanical Engineering Department should in general have training equivalent to that offered by the Institute in its undergraduate programs in any of several departments of engineering or science. The graduate program encompasses study in the areas of mathematics, physics, chemistry, electrical materials, continuum and dislocation mechanics, metallurgy, ceramics, elastomers, and plastics, as well as research. In general, two years are required for completion of the degree of Materials Engineer. General requirements for the degree of Materials Engineer include a qualifying examination, as described for the Mechanical Engineer Degree.

DOCTOR OF SCIENCE IN MECHANICAL ENGINEERING OR IN MATERIALS ENGINEERING

Admission to the doctoral program is granted only after the candidate has passed a qualifying examination; this should be taken as soon as possible after completing the Master's degree program. The requirements for the Doctor's degree include a Major program, a Minor program, a thesis, and qualification in two foreign languages with French, German, and Russian recommended.

The Major program, consisting 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 subjects in the student's area of principal interest, in addition to those taken to satisfy the requirements for the Master's degree; these, with the Minor program, usually require an additional two terms of work beyond the Master's degree.

The Minor program must be approved by the student's doctoral committee as well as by the department in which the minor is taken. It must conform to the provisions for the Graduate School in general, given in Section 3 of this Catalogue.

The qualifying examination must be completed before any program of research is undertaken. The language requirements should be fulfilled as early as possible in the program, so that the student will be capable of reading the foreign scientific literature on his proposed thesis subject before starting the actual research.

For his thesis, each candidate undertakes a program of research which will contribute significantly to his major field of interest. The Major program and the thesis are under the supervision of a doctoral committee selected by the student and his thesis supervisor. The doctoral committee makes an annual evaluation of the candidate's progress and conducts a final examination based on the thesis. While no fixed number of units is prescribed, the research usually requires at least one year of registration.

Candidates entering this doctoral program following award of the Master's degree in textile technology must meet the foregoing requirements but with a thesis in the field of fibrous materials.

Department of Metallurgy

JOHN CHIPMAN, PH.D., SC.D.
Professor of Metallurgy; Head of the Department

THOMAS BURNESS KING, PH.D.
Professor of Metallurgy; Executive Officer

ANTOINE MARC GAUDIN, SC.D.
Richards Professor of Mineral Engineering

JOHN TORREY NORTON, SC.D.
Professor of the Physics of Metals

FREDERICK HARWOOD NORTON, SC.D.
Professor of Ceramics

MORRIS COHEN, SC.D.
Professor of Physical Metallurgy

JOHN WULFF, D.SC.
Professor of Metallurgy

CARL FREDERICK FLOE, SC.D.
Professor of Metallurgy; Vice President, Research Administration

HOWARD FLOYD TAYLOR, M.S.
American Brake Shoe Company Professor of Foundry Metallurgy

HERBERT HENRY UHLIG, PH.D.
Professor of Metallurgy

MICHAEL BERLINER BEVER, DR. IUR., SC.D.
Professor of Metallurgy

NICHOLAS JOHN GRANT, SC.D.
Professor of Metallurgy

BENJAMIN LEWIS AVERBACH, SC.D.
Professor of Metallurgy

JOHN FRANK ELLIOTT, SC.D.
Professor of Metallurgy

CYRIL STANLEY SMITH, SC.D.
Institute Professor; Professor of Metallurgy

PHILIP LOUIS DE BRUYN, SC.D.
Associate Professor of Mineral Engineering

WILLIAM DAVID KINGERY, SC.D.
Associate Professor of Ceramics

WALTER ALAN BACKOFEN, SC.D.
Associate Professor of Metallurgy

CLYDE MELVIN ADAMS, JR., SC.D.
Associate Professor of Metallurgy

ROBERT EDWARD OGILVIE, SC.D.
Associate Professor of Metallurgy

MERTON CORSON FLEMINGS, JR., SC.D.
Associate Professor of Metallurgy

DAVID ALDEN THOMAS, SC.D.
Assistant Professor of Metallurgy

JERE HALL BROPHY, PH.D.
Assistant Professor of Metallurgy

GORDON EDWARD AGAR, SC.D.
Assistant Professor of Mineral Engineering

ALFRED ROBERT COOPER, JR., SC.D.
Assistant Professor of Ceramics

WILLIAM FULLER HOSFORD, JR., SC.D.
Assistant Professor of Metallurgy

ARTHUR WAYNE MULLENDORE, SC.D.
Assistant Professor of Metallurgy

GEORGE WILBUR PEARSALL, SC.D.
Assistant Professor of Metallurgy

LAWRENCE AMES SHEPARD, PH.D.
Assistant Professor of Metallurgy

ROBERT LOUIS COBLE, SC.D.
Assistant Professor of Ceramics

THOMAS RUSSELL CLEVENGER, JR., SC.D. *(Absent)*
Assistant Professor of Ceramics;
Ford Postdoctoral Fellow in Engineering

VENKATACHARI RAMAKRISHNA, PH.D.
Assistant Professor of Metallurgy

ROBERT MICHAEL ROSE, SC.D.
Assistant Professor of Metallurgy;
Ford Postdoctoral Fellow in Engineering

Instructors

CHARLES JOSEPH McMAHON, JR., B.SC.
GEORGE LANGFORD, III, S.B.
EDWARD TEHLE PETERS, B.A., M.S.
HUGH MORROW, III, S.B.
WALTER JAY DUFFIN, S.M.
JOSEPH IRWIN GOLDSTEIN, S.B.
MILTON DAY REED, S.B.
OWEN FRANCIS DEVEREUX, S.M.
JOHN PATRICK HAGER, M.S.
HEINZ ROMAN KILLIAS, S.M.

Technical Instructors

PAUL FREDERICK HUGHES
ARTHUR JEREMIAH GREGOR
PHILIP RENE LA FRANCE
GEORGE EARL SCHMIDT, JR.

Research Associates

ALFRED MILTON DUCA
ANTHONY ROGER ENTWISLE, PH.D.
KEN-ICHI HIRANO, SC.D.
NOBORU KOMATSU, D.ENG.
WILLIAM GORDON MOFFATT, SC.D.
Ford Postdoctoral Fellow in Engineering
HARALD RAMDOHR, D.TECH., D.ENG.
BAIDYANATH SAMADDAR, D.PH.
TOSHIO SATA, D.SC.
TANEKI TOKUDA, D.SC.
AUGUST FERDINAND WITT, PH.D.

Professors Emeriti

ROBERT SEATON WILLIAMS, PH.D.
Professor of Physical Metallurgy, Emeritus

MAURICE DEKAY THOMPSON, PH.D.
Professor of Electrochemistry, Emeritus

CARLE REED HAYWARD, S.B.
Professor of Process Metallurgy, Emeritus

VICTOR OLIVER HOMERBERG, SC.D.
Professor of Physical Metallurgy, Emeritus

METALLURGY

Metallurgy is the engineering science which deals with the production and utilization of metals and alloys and with the properties of metallic materials. It is a broad field, founded on the basic sciences of physics and chemistry and closely related to several branches of engineering. For many reasons it is a field of great importance to science and industry. Metals are of immense interest as basic components of our world, since they comprise about three-fourths of all the elements. Equally important is the fact that they are available in the earth's crust in large quantity and in such a form that they can be produced at a reasonable cost. Metals also have remarkable properties, which can often be modified to make them of particular use to man. They can be combined in an almost limitless number of ways, so that new alloys are constantly being developed to meet new needs or to serve old needs more adequately. As a result of their usefulness and availability, metals are now the working substance of modern engineering. The efficient operation of gas turbines, nuclear reactors, and many electrical devices of the future depends critically on metals as materials of construction.

The metallurgical engineer finds his services in great demand. Industries which are producing metals and converting them into useful products offer opportunities in plant operation and management to metallurgists with a Bachelor's degree. Metallurgists also play a prominent role in research on the nature and properties of metals and in the development of new processes and alloys to meet the increasingly severe demands of modern technology. While opportunities for this work exist for those with basic training, the demand is particularly active for persons who have taken graduate study. Preparation for graduate work may be an undergraduate major in metallurgy, physical science, or a field of engineering.

Materials science is a study of the structure, properties, and behavior of materials of all kinds, but especially of those engineering materials which are useful in structures, machines, or devices. Modern manufacturing operations utilize materials of many sorts, metallic and nonmetallic. Advanced engineering developments depend upon materials having such highly specialized properties as strength, toughness, elasticity, resistance to oxidation, or specific electrical or magnetic characteristics. Such properties must be maintained under extremes of high or low temperatures, under intense radiation, or in outer space. Selection of the right material for a given demand or the ability to invent and develop a new material depends upon a thorough grasp of materials science.

The Department of Metallurgy offers a wide range of subjects in metallurgy, mineral engineering, ceramics, and materials science and engineering, together with excellent opportunities for research. Brief descriptions of the major research facilities are given below.

The *Physical Metallurgy Laboratories* provide facilities for research on the constitution of metals and alloys, diffusion and reactions in the solid state, phase transformations, equilibrium diagrams of alloy systems, and the physical and mechanical properties of metals and alloys. The facilities include metallographic equipment, X-ray units for diffraction studies and radiography, testing apparatus, heat treating furnaces, and such specialized equipment as dilatometers, magnetometers, and an electron microscope.

The *Chemical Metallurgy Laboratories* provide a wide variety of facilities for investigations on roasting, extraction, reduction, smelting, distillation, refining, and the many chemical reactions involved in these processes. The steelmaking laboratory has facilities for preparation of experimental steels and for studies of the chemical reactions of molten iron and steel with gases, slags, and refractories.

The *Materials Processing Laboratories* are equipped for instruction and research in various aspects of the forming and joining of metals and nonmetallic materials. Modern facilities for the study of melting, casting, brazing, welding, powder pressing and sintering, and plastic deformation are available. Research programs in progress include the mechanical as well as metallurgical aspects of the subject.

In the *Mineral Engineering Laboratories*, facilities are available for research on comminution, sizing, dewatering, and the various separation methods of ores, minerals, and fuels. A modern laboratory is equipped for a detailed study of flotation. Complete microscopic equipment is available for mineral identification. The equipment is designed not only for the study of batch or continuous operations of the various processes, but also for the analysis of the basic physical and chemical phenomena on which the processes rest.

The *Ceramics Laboratories* are well equipped to carry out advanced research in the field which includes abrasives, cermets, coatings, electrical ceramics, glass, heavy clay products, pottery, and refractories. Facilities are available for process ceramics studies in fields such as raw material properties, forming processes, drying, melting, phase equilibria, chemical reactions, and firing and sintering of ceramic materials. Facilities are also available for physical ceramics studies in fields such as thermal properties, diffusion, surface properties, solid state reactions, physical and mechanical properties, and electrical and magnetic properties of ceramic materials.

The *High-Temperature Metals Laboratory* is concerned with the behavior of metals at elevated temperatures, and especially the effects of stress and time on this behavior. Other research is concerned with structural stability, deformation, fracture phenomena, and alloy development. Facilities for the preparation of complex alloys and for creep and stress rupture testing are available, as is equipment for measuring various physical and mechanical properties.

Research is carried out in the *Corrosion Laboratory* on general mechanisms of corrosive attack, leading to a better understanding of the various available methods for controlling corrosion and oxidation damage to metals and to formulation of new corrosion-resistant alloys. The Laboratory is equipped with a vacuum furnace and with modern facilities for electrochemical measurements and reaction rate studies.

Work on applied thermodynamics and kinetics is done in various laboratories of the Department and is concerned with such topics as calorimetry of metals and alloys, stability of metal sulfides and halides, and the electrochemistry of metallic systems.

To aid its research activities, the Department maintains an analytical laboratory and machine and instrument shops.

THE UNDERGRADUATE CURRICULA

Metallurgy (Course III-A)

The Course in Metallurgy offers opportunity for study in all phases of the science and engineering of metals. Because metallurgy is such a broad field, the curriculum contains a core of basic science and engineering and a wide choice of elective subjects.

The core consists primarily of mathematics, physics, chemistry, and the humanities, along with an introduction to metal science and the engineering principles involved in the extraction and application of materials. Students learn the basic thermodynamics, unit processes, and mechanical operations which underlie the making and shaping of metals; they also study the structure of metals, in preparation for understanding their properties and for selecting the right materials to meet service requirements. Students are introduced to the laws governing the alloying of metals and the principles by which new alloys may be developed.

The large amount of elective time permits students to pursue studies in related fields or to take additional subjects in metallurgical engineering, metal processing, or physical metallurgy. For example, those who are interested in ores and their beneficiation may elect subjects in mineral engineering and geology. A combined program of metallurgical and chemical engineering is suggested for those who wish to concentrate on the production of metals. For some students the curriculum may include a substantial amount of mathematics and physics. Still others may choose to direct their programs towards the study of machine design, stress analysis, and metal forming.

The Course leads to the degree of Bachelor of Science in Metallurgy; the curriculum requirements are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)					**176**
	PHYSICS 8.03 and 8.04[1] are preferred. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.				
DEPARTMENTAL PROGRAM					
	Required subjects				
3.00	THERMODYNAMICS I	4	0	6	
3.01	HEAT AND FLUID FLOW	4	3	5	
3.02	CHEMICAL METALLURGY	4	3	5	
3.10	METALLURGICAL PLANT VISITS	0	3	1	
3.20	THERMODYNAMICS II	4	0	4	
3.31	MATERIALS SCIENCE I	4	3	5	
3.50	X-RAY METALLURGY	2	2	4	
3.81	PRINCIPLES OF MATERIALS SEPARATION	4	3	5	
2.01	MECHANICS OF SOLIDS I	3	0	5	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
	THESIS		12		
					114
	Elective subjects				
	Unspecified (except that total THESIS units may not exceed 18)				**73**
	Total units required for the S.B. degree				**363**

[1] 8.041, if selected in place of 8.04, must be followed by 8.051 (or 8.05).

Materials Science (Course III-B)

The Course in Materials Science emphasizes the applications of physics and chemistry to phenomena of the solid state, thus providing a basis for scientific understanding of the structure and properties of materials. The Course includes studies of metals, ceramics, semi-conductors, glasses, plastics and other polymers, and of the properties of materials in general. It also covers methods by which materials are processed into useful forms. The curriculum provides an excellent basis for graduate work in materials engineering.

The Course leads to the degree of Bachelor of Science in Metallurgy. The curriculum requirements for the degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)					176
	PHYSICS 8.031 and 8.041[1] are preferred. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.				
DEPARTMENTAL PROGRAM					
	Required subjects				
3.00	THERMODYNAMICS I	4	0	6	
3.01	HEAT AND FLUID FLOW	4	3	5	
3.12	MATERIALS PROCESSING	3	3	6	
3.20	THERMODYNAMICS II	4	0	4	
3.31	MATERIALS SCIENCE I	4	3	5	
3.51	MATERIALS SCIENCE II	4	3	5	
2.01	MECHANICS OF SOLIDS I	3	0	5	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
6.18	FUNDAMENTALS OF ELECTRICAL ENGINEERING	3	2	5	
8.051	INTRODUCTION TO QUANTUM PHYSICS	4	0	5	
	THESIS		12		
					113
	Elective subjects				
	Unspecified (except that total THESIS units may not exceed 18)				74
Total units required for the S.B. degree					363

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

The planning of programs in either Course is begun under faculty supervision during the latter part of the second year. Faculty counseling in the selection of electives is readily available, but each student must assume the responsibility for planning his own program. A brochure describing the many possible programs may be obtained from the Department.

GRADUATE STUDY IN METALLURGY, MINERAL ENGINEERING, CERAMICS, AND MATERIALS ENGINEERING

Graduate work in the Department of Metallurgy comprises advanced studies and research on a selected topic. Laboratory investigations occupy a central position in all graduate programs. The descriptions of the laboratories given above have already introduced the various fields in which investigations may be carried out.

The Department offers the following graduate degrees: Master of Science in Metallurgy; Master of Science in Ceramics; Metallurgical Engineer; Mineral Engineer; Materials Engineer; Doctor of Science in Metallurgy; Doctor of Science in Ceramics; and Doctor of Science in Materials Engineering.

Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue. As a basic preparation for research work in this Department, it is required that all incoming graduate students register for 3.25 EXPERIMENTAL METHODS IN METALLURGY in the first term in which it is scheduled. This requirement may be waived upon presentation of evidence of similar training elsewhere.

FOR STUDENTS IN METALLURGY

Students whose preparation does not include the following subjects or their equivalents are expected to complete them in the early part of their graduate work:

HEAT AND FLUID FLOW (3.01)
MATERIALS SCIENCE I (3.31)
PHYSICAL CHEMISTRY I (5.61)
PHYSICAL CHEMISTRY II (5.62)
or
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)

For students who are graduates of other departments in science and engineering and who wish to enroll for advanced degrees in the Department of Metallurgy, other evidence of preparation may be accepted in lieu of the above requirements.

FOR STUDENTS IN MINERAL ENGINEERING

Students whose preparation does not include the following subjects or their equivalents are expected to complete them in the early part of their graduate work:

HEAT AND FLUID FLOW (3.01)
PRINCIPLES OF MATERIALS SEPARATION (3.81)
PHYSICAL CHEMISTRY I AND II (5.61, 5.62)

FOR STUDENTS IN CERAMICS

There are no special prerequisites for graduate study in ceramics — each applicant will be considered individually. In general, graduates of

courses in ceramics, ceramic engineering, chemistry, chemical engineering, mechanical engineering, metallurgy, materials science, or physics will be qualified. All entering graduate students are required to register for 3.70 CERAMICS in the first term in which it is scheduled, or present evidence of similar training elsewhere.

FOR STUDENTS IN MATERIALS ENGINEERING

The general Institute requirements for admission, given in Section 3 of this Catalogue, are sufficient. Programs will be arranged on an individual basis, depending on the preparation and interests of the student. Those students who have not had the following subjects or their equivalent are expected to complete them in the early part of their graduate work:

MATERIALS SCIENCE I (3.31)
PHYSICAL CHEMISTRY I (5.61)

The Graduate Degrees

The specifications for the degrees of Master of Science in Metallurgy, Master of Science in Ceramics, Metallurgical Engineer, Mineral Engineer, Materials Engineer, Doctor of Science in Metallurgy, Doctor of Science in Ceramics, and Doctor of Science in Materials Engineering are as set forth in Section 3 of this Catalogue.

Candidates for the doctorate in metallurgy, ceramics, or materials engineering are required to demonstrate their ability to read scientific literature in German and in one other foreign language in which a significant technological literature exists.

Assistantships and Fellowships

The Department offers assistantships and fellowships for graduate study. Research and teaching assistantships are available, on a full- or half-time basis, in all of the fields in which the Department is active. Further information about assistantships and fellowships may be obtained from the chairman of the Departmental Committee on Graduate Students.

Department of Naval Architecture and Marine Engineering

HORTON GUYFORD STEVER, PH.D., SC.D.
Professor and Head of the Department
JOHN HARVEY EVANS, B.ENG.
Professor of Naval Architecture; Executive Officer
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus; Lecturer
GEORGE CHARLES MANNING, SC.D.
Professor of Naval Architecture, Emeritus; Lecturer
EDWARD SENTMAN ARENTZEN, S.M.
Captain, U. S. Navy
Professor of Naval Construction
MARTIN AARON ABKOWITZ, PH.D.
Professor of Naval Architecture
EVERS BURTNER, S.B.
Associate Professor of Naval Architecture and Marine Engineering, Emeritus; Lecturer
SHANNON CURTIS POWELL, DOTT.ING.
Associate Professor of Marine Engineering
PHILIP MANDEL, B.S.
Associate Professor of Naval Architecture
JOHN ROBERT BAYLIS, NAV.E.
Lieutenant Commander, U. S. Navy
Associate Professor of Naval Engineering
JUSTIN ELLIOT KERWIN, PH.D.
Assistant Professor of Naval Architecture
ERNST GABRIEL FRANKEL, MAR.MECH.E.
Assistant Professor of Marine Engineering

Lecturer

DONALD ROSS, PH.D.

Professors Emeriti

LAWRENCE BOYLSTON CHAPMAN, S.B.
Professor of Marine Transportation and Marine Engineering, Emeritus
HENRY EASTIN ROSSELL, S.M.
Professor of Naval Construction, Emeritus
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus; Lecturer
GEORGE CHARLES MANNING, SC.D.
Professor of Naval Architecture, Emeritus; Lecturer
LAURENS TROOST, IR.
Professor of Naval Architecture, Emeritus
EVERS BURTNER, S.B.
Associate Professor of Naval Architecture and Marine Engineering, Emeritus; Lecturer

Naval architecture and marine engineering encompasses one of the broadest of engineering fields. It is concerned with all aspects of vehicles operating below and just above the sea surface, as well as on it. Its interests range from the application of the most advanced engineering science disciplines to the unusual, and sometimes specialized, problems encountered in such vehicles; through the synthesis of all the systems, components, and structures of which they are comprised; to their construction; and to the management of shipping enterprises. These activities have the common purpose of creating new or better ships of all types by applying the latest developments in science. In keeping with this purpose, the Department of Naval Architecture and Marine Engineering emphasizes both the application of present scientific knowledge and the development of each student's ability to interpret and apply future knowledge in all disciplines which are pertinent.

The educational program of the Department leads to a broad engineering competence, with a core content which includes application of fundamental principles to problems in naval architecture and marine engineering. It is based on a wide-ranging foundation of fundamental science and is an excellent background for almost any later special activities based on the physical sciences. A flexible curriculum, a departmental faculty with wide and continuing industrial experience, and unusually close faculty-student contact all contribute to a sound and effective educational training.

The Department offers two programs of study for civilian students: Naval Architecture and Marine Engineering (Course XIII), with both undergraduate and graduate programs; and Shipping and Shipbuilding Management (Course XIII-B), a combination of undergraduate and graduate study. In addition, it offers a graduate program for selected officers of the U.S. Navy, U.S. Coast Guard, and accredited foreign navies. This is designated as Naval Construction and Engineering (Course XIII-A).

THE UNDERGRADUATE PROGRAMS

Naval Architecture and Marine Engineering (Course XIII)

This curriculum is customarily followed by those interested in the technical aspects of the marine industry — naval architects, marine engineers,

and those with more specialized interests. All take the same required subjects in mathematics, science, engineering fundamentals, and humanities, in addition to subjects in the various phases of ship design, construction, and marine engineering. A thesis — a report of an independent research or study project — is required of every student before he graduates. The elective part of the program, which for an average student comprises eight to ten subjects, can be made up of subjects of general or specialized interest within or outside the department; or it may be chosen to satisfy well-defined objectives in special fields, such as hydrodynamics, structures, oceanography, noise and vibration, and hydroelasticity. Throughout the curriculum the emphasis is on developing logic and originality, so that graduates may make an orderly attack on any engineering problem.

The undergraduate curriculum is given below. Substitution for departmentally prescribed subjects is encouraged when appropriate to a student's educational objective and particularly when more effective sequencing of subjects can result, provided that the same broad coverage is maintained. Within departmental subjects, the time spent in design emphasizes the underlying engineering basis of design, rather than the mere presentation of results. Further, since both naval architecture and marine engineering are based in the general field of mechanical engineering, students spend much of their class time in the Department of Mechanical Engineering.

This four-year Course leads to the degree of Bachelor of Science in Naval Architecture and Marine Engineering. The curriculum requirements for this degree are given below:

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 83*)		**176**
	PHYSICS 8.03 and 8.04 or 8.031 and 8.041[1] must be taken. ECONOMIC PRINCIPLES I (14.01) is required as one of the humanities and social science electives.	
DEPARTMENTAL PROGRAM		
	Required subjects	
13.00	PRINCIPLES OF NAVAL ARCHITECTURE 4 1 7	
13.10	SHIP STRUCTURAL ANALYSIS AND DESIGN 3 3 6	
13.20	ENERGY CONVERSION SYSTEMS AND COMPONENTS 4 1 7	
13.30	MECHANICAL VIBRATION 3 0 5	
13.40	INTRODUCTORY SHIP DESIGN 1 6 2	
2.01	MECHANICS OF SOLIDS I 3 0 5	
2.02	MECHANICS OF SOLIDS II 3 0 5	
2.25	FLUID MECHANICS 4 0 8	
2.403	THERMODYNAMICS 4 0 8	
3.14	ENGINEERING MATERIALS 4 2 4	
18.05	ADVANCED CALCULUS FOR ENGINEERS 3 0 6	
	THESIS 9	
		121
	Elective subjects	
	Unspecified, except that a minimum of three subjects in engineering or science must be included and that a single beginning subject in a foreign language may not be taken for credit.	**63**
Total units required for the S.B. degree		**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

Shipping and Shipbuilding Management (Course XIII-B)

This Course is intended to satisfy the formal educational requirements of students primarily interested in the business and management phases of the marine industry. Students entering this field must have a firm technical background; hence all the departmentally prescribed subject requirements of the Naval Architecture and Marine Engineering curriculum must be satisfied prior to graduation. According to their interests, students select areas of concentration in business and management and study undergraduate and graduate subjects in M.I.T.'s Department of Economics and Social Science and School of Industrial Management. They also broaden their experience by electing advanced subjects offered by other departments at the Institute.

The coordinated program of undergraduate electives and graduate study for Course XIII-B will be approved after consultation with and concurrence of the Department of Economics and Social Science and the School of Industrial Management, as appropriate. Compliance with all regulations of the Graduate School is required.

This five-year program leads to two degrees: the Bachelor of Science in Naval Architecture and Marine Engineering and the Master of Science in Shipping and Shipbuilding Management, awarded simultaneously at the end of the graduate (fifth) year.

THE CURRICULUM IN SHIPPING AND SHIPBUILDING MANAGEMENT (COURSE XIII-B)

The undergraduate curriculum requirements are the same as for Course XIII, except that the 9 units of undergraduate thesis are allotted to additional professional subjects, and that concentration in Economics (Field 6) and Labor Relations (Field 8) of the humanities program is not permitted.

The graduate requirement is 67 units of graduate study and 29 units of THESIS, a total of 96 units. Up to a total of 11 units of additional THESIS may be taken with a corresponding reduction of the units of graduate study.

GRADUATE STUDY IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

The Department of Naval Architecture and Marine Engineering offers four graduate degrees in this field: Master of Science, Naval Architect, Marine Mechanical Engineer, and Doctor of Science. In addition, the Course in Naval Construction and Engineering (Course XIII-A) offers the degree of Naval Engineer.

A program of graduate study in the Department is almost entirely under the control of the student. He is assisted in his planning by the Graduate Registration Officer who is his faculty adviser. An acceptable graduate program of 96 credit units, which is usually completed in one academic year if based on an undergraduate curriculum equivalent in scope to that offered by this Department, leads to the degree of Master of Science in Naval Architecture and Marine Engineering; a two-year program leads to the degree of Naval Architect or Marine Mechanical Engineer. Students with a less broad undergraduate background usually require more time; or they may follow a program leading to a Master of Science without specification, which requires equally high standards of academic performance.

To obtain the degree of Doctor of Science in Naval Architecture and Marine Engineering usually requires a minimum of three years of graduate work.

Subjects offered in this Department which are available to civilian graduate students include the following:

PRINCIPLES OF SHIP DESIGN (13.41)
PRELIMINARY DESIGN OF SHIPS (13.42)
ADVANCED TOPICS IN SHIP DESIGN (13.93)
ADVANCED HYDROMECHANICS OF SHIP DESIGN (13.03)
SPECIAL PROBLEMS IN NAVAL ARCHITECTURE AND MARINE ENGINEERING (13.91)
MECHANICAL VIBRATION (13.31)
SHIPPING ECONOMICS (13.92)
PROPULSION HYDRODYNAMICS (13.02)
HYDROACOUSTICS (13.95)

Most other departments in the Schools of Engineering and Science offer subjects which are appropriate to graduate programs in Naval Architecture or Marine Engineering. Among such subjects are those in mathematics, physics, acoustics, dynamics, structures, mechanics of fluids and solids, controls, computers, electrical engineering, nuclear engineering, materials, gas turbines, internal combustion engines, thermodynamics, and heat transfer.

Entrance Requirements for Graduate Study

In addition to the general requirements for admission described in Section 3 of this Catalogue, the undergraduate preparation should be equal, in quality, quantity, and breadth of coverage to the Institute's undergraduate curriculum in Naval Architecture and Marine Engineering. Successful study in an acceptable program of graduate work requires a competence substantially equivalent to that represented by this curriculum in each of the following areas:

Strength of materials
Dynamics
Fluid mechanics
Heat engineering
Engineering materials
Naval architecture
Ship structures
Marine engineering
Ship design

If undergraduate preparation has been significantly less intensive in any of these areas, the deficiencies must be removed prior to the award of any of the degrees implying specification. This may be accomplished concurrently with graduate work if the deficiencies are not extensive. Undergraduate subjects so required will in some cases be accepted by the Department in partial fulfillment of the advanced degree requirements. A strictly limited number of subjects, in no case exceeding 24 units of registration, will be accepted on this basis. Somewhat less intensive undergraduate work in areas represented by subjects of instruction given in this Department is appropriate for candidates for the degree of Master of Science without specification, if accompanied by correspondingly increased competence in other areas.

Departmental Requirements for Advanced Degrees

The program of studies for an advanced degree is largely under control of the student, acting with the advice of his Registration Officer, but it must meet the general requirements specified in Section 3 of this Catalogue and must be acceptable to the Departmental Committee on Graduate Students.

Unless special approval is given by this Committee, candidates for any graduate degree other than the Master of Science in Shipping and Shipbuilding Management are expected to include in their programs at least one term of advanced mathematics beyond the requirements of the Department's undergraduate curriculum. A program for an Engineer degree should also include two subjects in the area of economics or industrial management, and at least 20 units of comprehensive design, such as PRELIMINARY DESIGN OF SHIPS (13.42), or the equivalent. A single thesis will generally be acceptable for both the Master of Science and Engineer degrees, provided it is appropriate to the specification of the latter degree. A reading knowledge of technical material in two foreign languages is required for the Doctor of Science degree.

The Department interprets the field of naval architecture and marine engineering rather broadly in connection with the requirements for a degree with or implying specification. Thus a program for a degree with specification usually includes considerable work in other departments, such as mathematics, aeronautics and astronautics, or civil or mechanical engineering. The thesis may be in another department if it is directly applicable to naval architecture and marine engineering.

Assistantships and Scholarships

A limited number of part-time assistantships in connection with teaching and research duties are available each year. In addition to the M.I.T. fellowships and scholarships, some industrial fellowship aid is available, generally to students who are graduates of this Department or who have completed some graduate work in the Department. Fellowships are also awarded each year by the Society of Naval Architects and Marine Engineers. These latter are valid for study at any institution of the recipient's choice and are usually awarded to applicants who have previously evidenced strong interest in the field of naval architecture and marine engineering, either through their education or their professional work. Prospective students are invited to communicate with the Head of the Department regarding any of these educational and financial opportunities. Applications for the Society of Naval Architects and Marine Engineers Awards are made directly to that Society. Inquiries for the fall term should be made early in the preceding spring term.

Naval Construction and Engineering (Course XIII-A)

This Course was originally set up at the request of the United States Navy to provide appropriate academic background for officers who would later supervise the design and construction of combat vessels. In addition to general engineering and science and a core program of naval architecture and marine engineering subjects especially arranged for Course XIII-A, each student follows one of several specialized curricula in aspects of, or applicable to, Naval Construction and Engineering.

In addition to study at the Institute for seven terms, the Course includes appropriate experience during the summers after the first and second years.

The Course leads to the degree of Master of Science in Naval Architecture and Marine Engineering and the degree of Naval Engineer, awarded simultaneously at the end of the program of study.

Admission to the Course is subject to the approval of the U.S. Navy and requires undergraduate preparation equivalent to that offered by the U.S. Naval and Coast Guard Academies.

Department of Nuclear Engineering

MANSON BENEDICT, PH.D.
Professor of Nuclear Engineering; Head of the Department
IRVING KAPLAN, PH.D.
Professor of Nuclear Engineering
THEOS JARDIN THOMPSON, PH.D.
Professor of Nuclear Engineering; Director of the M.I.T. Reactor
DAVID JOHN ROSE, PH.D.
Professor of Nuclear Engineering
EDWARD ARCHIBALD MASON, SC.D.
Associate Professor of Nuclear Engineering
MELVILLE CLARK, JR., PH.D.
Associate Professor of Nuclear Engineering
WARREN PHILIP CHERNOCK, M.S.
Associate Professor of Nuclear Engineering (Visiting)
GORDON LEE BROWNELL, PH.D.
Associate Professor of Nuclear Engineering
ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.
Associate Professor of Nuclear Engineering
NORMAN CARL RASMUSSEN, PH.D.
Associate Professor of Nuclear Engineering
HENRI FENECH, SC.D.
Assistant Professor of Nuclear Engineering
KENT FORREST HANSEN, SC.D.
Assistant Professor of Nuclear Engineering
THOMAS HENDERSON DUPREE, PH.D.
Assistant Professor of Nuclear Engineering

Lecturer
SAMUEL LEVIN, S.B.

Research Associates
EDWARD JAMES BARNETT
LINCOLN CLARK, JR., A.B.
LYALL ROBERT ENSTICE, JR., B.S.
JAMES WATERBURY GOSNELL, M.S.
DAVID DAYTON LANNING, B.A.
AMEDEUS EDWARD PROFIO, JR., S.B.
DANIEL SCHWARTZ, S.M.
ERNEST THOMPSON, B.SC.
WILLIAM MACLAREN TRENHOLME, B.E.E., M.A.

NUCLEAR ENGINEERING

Nuclear engineering deals with the practical application of scientific knowledge of nuclear reactions and radiations. Today, fission is the nuclear reaction of greatest practical importance. Much of present-day nuclear engineering is concerned with use of the fission reaction for production of heat and power, transmutation of elements, and production of neutrons, gamma radiation, and radioisotopes. In the years ahead, the fission of nuclear fuels is expected to supplement and in many areas to replace the combustion of chemical fuels for producing power.

In the long-term evolution of nuclear engineering, thermonuclear reactions (fusion) may well play at least as important a role as fission does now. Development of a practical and economic means of producing power from the controlled fusion of deuterium would provide the world with an inexhaustible store of energy. Thus it is also important for the nuclear engineer to be familiar with the principles of fusion technology.

Recognizing that fission reactions and fusion reactions are both important areas of nuclear engineering, the Department offers optional graduate curricula either in fission technology or in thermonuclear processes.

Nuclear engineering makes use of a synthesis of many skills. Important contributions to the solution of problems in the field are being made by men trained in physics, chemistry, and metallurgy and in chemical, civil, electrical, and mechanical engineering. The program in nuclear engineering at M.I.T. is open to men with undergraduate training in these and related fields. It aims to teach the basic principles of nuclear reactors and process technology and to show the student how his field of undergraduate specialization may be applied to nuclear engineering problems. The program should interest graduate students who wish to specialize in nuclear engineering as well as graduate students or advanced undergraduates in other departments who wish to obtain some familiarity with nuclear technology.

The Department offers the degrees of Master of Science and Doctor of Science in Nuclear Engineering and of Nuclear Engineer. No undergraduate degree is offered.

Registration in the Department and in all subjects of instruction is open to all students with the requisite prior training, with the exception

of the Engineering Practice School at Oak Ridge. Attendance at this Practice School is limited to United States citizens approved by the U.S. Atomic Energy Commission.

RESEARCH FACILITIES

The Department's educational program is supported by a number of outstanding experimental facilities for advanced basic research in nuclear engineering.

The M.I.T. Research Reactor

The M.I.T. Research Reactor is a 2000 kw. reactor fueled with U-235 and cooled and moderated by heavy water. Completed late in the spring of 1958, it is one of the finest university research reactors in the world. It provides first-hand experience in the design, performance, and operation of nuclear reactors and serves as a source of radiations for use in laboratory instruction on radiation detection and measurement methods. A variety of research projects make use of the intense sources of neutrons and gamma rays produced by the reactor. Areas of research which the reactor has opened up include: neutron physics, cross-section measurements, reactor physics, solid-state studies based on neutron diffraction, radiochemistry of the fission products, physics of neutron-capture processes, activation analysis, research with short-lived radioisotopes, radiation-catalyzed chemical reactions, radiation-induced biological effects, radiation therapy, and radiation-damage studies of materials.

Other Research Facilities

The Department has a well-equipped nuclear instrumentation laboratory 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. M.I.T.'s I.B.M. Type 709 electronic computer is used extensively in research and graduate instruction.

The Institute's Research Laboratory of Electronics contains extensive facilities for studies in plasma dynamics. Typical areas of research include production and confinement of plasmas and their interaction in electromagnetic fields.

The Oak Ridge Engineering Practice School

The Engineering Practice School at Oak Ridge, Tennessee, (described in Section 1 of this Catalogue) is of special interest to graduate students in nuclear engineering. Students enrolled in the School are assigned technical problems which have arisen in the design, development, and operation of the plants which are operated for the Atomic Energy Commission by the Union Carbide Nuclear Company. Under the direction of resident M.I.T. faculty, students learn to apply their technical skills and engineering judgment to the solution of problems encountered in all phases of the atomic energy field, from the production and refining of fissionable fuel to the design and operation of nuclear reactors.

UNDERGRADUATE PREPARATION FOR NUCLEAR ENGINEERING (COURSE XXII)

An undergraduate degree in physics, chemistry, or metallurgy, or in chemical, civil, mechanical, or electrical engineering offers suitable preparation for graduate study in nuclear engineering, provided the following M.I.T. undergraduate subjects or their equivalent have been included.

Physics: Three years, including atomic and nuclear physics.

Mathematics: Three years, including ADVANCED CALCULUS FOR ENGINEERS (18.05, 18.06).

Thermodynamics: 2.40, 2.403, 3.20, or 10.13.

Heat Transfer: 2.43, 2.50, 2.58, or 10.31.

Electromagnetic Theory: 6.07T or 8.72 for those students concentrating in the thermonuclear area.

Prospective graduate students should make every effort to take these subjects before starting graduate study. Students deficient in one or more of them may make up their deficiencies after admission to graduate study, but they will need more time to complete the graduate program.

Students who expect to apply for admission to the graduate Course in Nuclear Engineering should discuss their undergraduate programs with the Department's Registration Officer, preferably before the end of their junior year.

GRADUATE STUDY IN NUCLEAR ENGINEERING

Details of the requirements for graduate degrees are given in the following paragraphs.

MASTER OF SCIENCE IN NUCLEAR ENGINEERING

The general requirements for this degree are listed in Section 3 of this Catalogue. Subjects desirable for candidates for the Master of Science in Nuclear Engineering who elect the fission technology option are:

NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR REACTOR PHYSICS II (22.22)
NUCLEAR REACTOR ENGINEERING (22.23)
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)
NUCLEAR PHYSICS FOR ENGINEERS I (8.531T)
NUCLEAR PHYSICS FOR ENGINEERS II (8.532T)

Subjects desirable for candidates electing the thermonuclear process option are:

NUCLEAR REACTOR PHYSICS I (22.21)
INTRODUCTION TO THERMONUCLEAR PROCESSES (22.61)
THERMONUCLEAR PROCESSES (22.62)
ELECTROMAGNETIC THEORY I (8.721)
NUCLEAR PHYSICS FOR ENGINEERS I (8.531T)
NUCLEAR PHYSICS FOR ENGINEERS II (8.532T)

Other studies may be chosen in accordance with the student's inclination and preparation.

Students with full undergraduate preparation normally need one full year to complete the requirements for the Master of Science degree, although occasionally a fall and spring term are sufficient.

Work in the Engineering Practice School at Oak Ridge may be accepted in place of a thesis for candidates for the Master of Science degree. Students with adequate undergraduate preparation who elect to attend this Practice School will ordinarily require a minimum of fifteen months to obtain the degree. Normally the student completes his program of studies at the Institute during a fall and spring term and attends the Practice School during the following fall term.

NUCLEAR ENGINEER

The program of study leading to the Nuclear Engineer degree is intended to provide a broader knowledge of nuclear engineering than is possible in the Master's program and to develop competence in engineering application or design. The general requirements for the Engineer degree are given in Section 3 of this Catalogue.

The program of 192 units required must be approved by the department and should provide a broad education for creative work in the field of nuclear engineering.

This program must include the completion of a substantial engineering design project of approximately 40 credit units, which may be represented by the Master's and/or Engineer theses. In any case, one thesis of at least 20 credit units is necessary.

DOCTOR OF SCIENCE IN NUCLEAR ENGINEERING

The program of study leading to this degree aims to give a comprehensive knowledge of nuclear engineering and to develop competence in engineering research. General requirements for the doctorate are listed in Section 3 of this Catalogue. Before the student may start his doctoral research, he is required to pass a comprehensive general examination demonstrating competence in physics, mathematics, and engineering fundamentals.

Graduate subjects on which all candidates for the doctorate are examined include:

NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)
NUCLEAR PHYSICS FOR ENGINEERS (8.531T, 8.532T)
INTRODUCTION TO THERMONUCLEAR PROCESSES (22.61)

Candidates for the doctorate who elect the fission option will also be examined on:

NUCLEAR REACTOR PHYSICS II (22.22)
NUCLEAR REACTOR ENGINEERING (22.23)

Candidates who elect the thermonuclear option will also be examined on:

ELECTROMAGNETIC RADIATION (8.72)
THERMONUCLEAR PROCESSES (22.62)

Doctoral research may be undertaken either in nuclear engineering or in a related field in another department. Appropriate areas of research include: reactor statics and dynamics, cross-section measurements, neutron diffraction studies, plasma physics, hydromagnetics, nuclear metallurgy, feedback control, heat transfer, nuclear instrumentation, shielding, transport theory, nuclear chemistry, direct conversion of nuclear heat to electricity, chemical and biological effects of radiation, effect of radiation on reactor materials, fuel cycles for nuclear reactors, solvent extraction of metals, isotope separation, and treatment of radioactive wastes.

Language requirements for the doctorate are a reading knowledge of scientific literature in two languages selected from French, German, and Russian.



SCHOOL OF HUMANITIES AND SOCIAL SCIENCE 7.

The Dean of the School of Humanities and Social Science describes its many activities in serving M.I.T. Courses and granting M.I.T. degrees.

The School of Humanities and Social Science embraces the work of a faculty divided into three cross-disciplinary departments. The Department of Economics and Social Science includes the faculty interested in economics, political science, psychology, labor relations, and sociology; the Department of Humanities includes the faculty concerned with history, literature, music, and philosophy; the Department of Modern Languages numbers those whose interest is in modern languages, literature in foreign languages, comparative literature, and linguistics.

This faculty has three complementary missions. The School is in the first place responsible for much of the general education required of every undergraduate at M.I.T., regardless of his area of specialization. In this role members of the faculty, mostly, though not all, drawn from the Department of Humanities, guide every freshman and sophomore through the common core curriculum in the humanities; later, all of the faculties of the School meet their share of juniors or seniors, as these upperclassmen are required to elect one field for concentrated study in the humanities and social sciences. The core curriculum and fields for subsequent study are described in Section 2 of this Catalogue.

A second mission of the School involves offerings leading to the degree of Bachelor of Science. There are currently four such programs, two in the Department of Economics and two in the Department of Humanities. These four degree programs all require a second major either in some branch of science or in a branch of engineering. In this respect they differ in form from curricula in similar fields at other institutions.

There are other differences of perhaps greater import. M.I.T., as an institution polarized around science and engineering, accepts the view that science and engineering are important elements in all modern life, that they are to be embraced rather than to be feared. Thus these degree offerings in the School of Humanities and Social Science require the same rigor in science and engineering — though not the depth of accomplishment — that is required of scientists and engineers; the programs include these subjects as a fundamental part of contemporary culture. Far from regarding the scientific study as antithetical to the humanistic, they recognize the essential unity of serious study in any area. Thus these programs may be particularly well fitted to prepare the right kind of young man or woman for living in the modern world.

The student whose formal education is completed with his four-year degree is likely to find that the preparation for modern life afforded by these Courses in economics, political science, or humanities is unique and effective; if he intends to continue to higher degrees, he will

find that he is well prepared for study in a law school, medical school, or graduate school of industrial management; he will also find it possible to continue at once in graduate work in either of the two majors he has carried as an undergraduate. Thus the curriculum is an unusually flexible and open-ended one.

The School of Humanities and Social Science accepts a third part of its mission — to enlarge the frontiers of knowledge — with enthusiasm, and indeed would regard the achievement of the other two parts as much less probable were it not for research and graduate work. Few members of the faculty of this School are not engaged in research and publication, ranging from individual efforts to the large group engagement of the Center for International Studies, which is also a part of the School. Doctorates can be earned in economics, political science, and linguistics.

The extent of the graduate work and research is perhaps the feature which most distinguishes the School of Humanities and Social Science at M.I.T. from those to be found in other technological institutions. The extent to which the members of this faculty are in close contact with the faculties of science and engineering is perhaps what most distinguishes it from those of nontechnological institutions. We believe this to be a happy pair of circumstances, a pair which makes every part of our student offering richer.

JOHN E. BURCHARD

THE UNDERGRADUATE CURRICULA IN THE SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

The S.B. curricula in the School of Humanities and Social Science consist of a program of general education, emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements), and groupings of subjects which combine work in one field of engineering or science with a concentration in one of the humanities or social science disciplines (the Departmental Programs). The General Institute Requirements are given below. The Departmental Programs are given by each department on the following pages.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities or social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

				Total units
GENERAL INSTITUTE REQUIREMENTS				
5.01	[1]GENERAL CHEMISTRY	4	2	5
5.02	[1]GENERAL CHEMISTRY	4	2	5
8.01	[1]PHYSICS	4	1	6
8.02	[1]PHYSICS	4	1	6
8.03	PHYSICS			
or		4	1	5
8.031	PHYSICS			
8.04	PHYSICS			
or		4	1	5
8.041	[2]PHYSICS			
18.01	[1]CALCULUS	3	0	6
18.02	[1]CALCULUS	3	0	6
18.03	CALCULUS	3	0	6
18.04	DIFFERENTIAL EQUATIONS	3	0	6
21.01	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.02	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.03	MODERN WESTERN IDEAS AND VALUES	3	0	5
21.04	MODERN WESTERN IDEAS AND VALUES	3	0	5
	[1]*Freshman electives*		12	
	[2]*Humanities and social science electives*		32	
				176

A thesis or project of at least 9 units is required in each curriculum in the School of Humanities and Social Science. Each Departmental Program states the minimum thesis units required in that curriculum.

[1] Subjects of the common first-year program. See pages 38–39.
[2] 8.041, if selected, must be followed by 8.051 (or 8.05).
[3] See pages 39–42 for the humanities and social science program.

Department of Economics and Social Science

ROBERT LYLE BISHOP, PH.D. (*Absent*)
Professor of Economics; Head of the Department

RALPH EVANS FREEMAN, M.A., B.LITT.
Professor of Economics, Emeritus; Lecturer; Acting Head of the Department

NORMAN JUDSON PADELFORD, PH.D., LL.D.
Professor of Political Science

PAUL ANTHONY SAMUELSON, PH.D.
Professor of Economics

CHARLES ANDREW MYERS, PH.D.
Professor of Industrial Relations

HAROLD ADOLPH FREEMAN, S.B.
Professor of Statistics

CHARLES POOR KINDLEBERGER, PH.D.
Professor of Economics

KARL WOLFGANG DEUTSCH, PH.D.
Professor of Political Science (Visiting)

MAX FRANKLIN MILLIKAN, PH.D.
Professor of Economics

PAUL NARCYZ ROSENSTEIN-RODAN, DR.RER.POL.
Professor of Economics

EVERETT EINAR HAGEN, PH.D.
Professor of Economics

WALT WHITMAN ROSTOW, PH.D. (*Absent*)
Professor of Economic History

EVSEY DAVID DOMAR, PH.D.
Professor of Economics

DANIEL LERNER, PH.D.
Professor of Sociology

EDGAR CARY BROWN, PH.D.
Professor of Economics

ITHIEL DE SOLA POOL, PH.D.
Professor of Political Science

ROBERT MERTON SOLOW, PH.D.
Professor of Economics

MORRIS ALBERT ADELMAN, PH.D.
Professor of Economics

PAUL PIGORS, PH.D.
Professor of Industrial Relations

LUCIAN WILMOT PYE, PH.D.
Professor of Political Science

HANS-LUKAS TEUBER, PH.D.
Professor of Psychology

ROGER WILLIAM BROWN, PH.D.
Professor of Social Psychology

WILLIAM KAUFMANN, PH.D.
Professor of Political Science

KENNETH BERRILL, M.S.
Professor of Economic History (Visiting)

LINCOLN PALMER BLOOMFIELD, PH.D.
Associate Professor of Political Science

EDWIN KUH, PH.D. (*Absent*)
Associate Professor of Economics

ABRAHAM J. SIEGEL, M.A.
Associate Professor of Industrial Relations

ROBERT COLDWELL WOOD, PH.D.
Associate Professor of Political Science

FRANCIS MICHEL BATOR, PH.D.
Associate Professor of Economics

DAVIS HUMPHREY HOWES, 3D, PH.D.
Associate Professor of Psychology

JOHN ARTHUR SWETS, PH.D.
Associate Professor of Psychology

LOUIS LEFEBER, PH.D.
Associate Professor of Economics

MYRON WEINER, PH.D. (*Absent*)
Associate Professor of Political Science

ELSPETH DAVIES ROSTOW, A.M. (*Absent*)
Assistant Professor of History

LAURENCE WOODWARD MARTIN, PH.D. (*Absent*)
Assistant Professor of Political Science

ALBERT KEINOSUKE ANDO, PH.D.
Assistant Professor of Economics

DAVID MARVIN GREEN, PH.D.
Assistant Professor of Psychology

SETH PHILLIP TILLMAN, PH.D. (*Absent*)
Assistant Professor of Political Science

ROBERT EVANS, JR., PH.D.
Assistant Professor of Industrial Relations

RONALD MELZACK, PH.D.
Assistant Professor of Psychology

MICHAEL ARTHUR WALLACH, PH.D.
Assistant Professor of Psychology

FRANKLIN MARVIN FISHER, PH.D.
Assistant Professor of Economics

FREDERICK WARD FREY, PH.D.
Assistant Professor of Political Science

DONALD LAWRENCE MORTON BLACKMER, A.M.
Assistant Professor of Political Science

STEPHEN HERBERT HYMER
Assistant Professor of Economics

Lecturers

ROBERT ALLEN GARDNER, PH.D.
WILLIAM EDGAR GRIFFITH, PH.D.
ROBERT HAROLD ISAACS, A.B.
FREDERICK GEORGE LESIEUR

Instructors

THEODORE HARRISON, M.A.
NICHOLAS NYARY, M.A.
BRADBURY SEASHOLES, M.A.
ANTHONY CLEMENT RAYNER, M.A.
BRUCE MARTIN RUSSETT, M.A.

Professors Emeriti

FLOYD ELMER ARMSTRONG, LL.D.
Professor of Economics and Finance, Emeritus

DONALD SKEELE TUCKER, PH.D.
Professor of Economics, Emeritus

RALPH EVANS FREEMAN, M.A., B.LITT.
Professor of Economics, Emeritus; Lecturer

ECONOMICS AND SOCIAL SCIENCE

This Department is concerned with the scientific study of people both as individuals and as members of society. Such study has a place at M.I.T. not only because engineers go into business and participate in the government of the country, but also because the activities of engineers and scientists have profound effects on economic and political activity. M.I.T. believes that its students, by learning something about themselves and about the social environment in which they live and work, will have greater satisfaction in life and become more valuable members of their professions.

Economics has long been a part of M.I.T. education. Three sections have now been developed within the Department: Industrial Relations, Political Science, and Psychology. These different approaches to the study of human behavior complement each other and afford a number of programs from which students may choose. An examination of the curricula listed below will reveal considerable flexibility within each program.

THE UNDERGRADUATE CURRICULA

Economics, Politics, and Engineering (Course XIV-A)

Economics, Politics, and Science (Course XIV-B)

The Courses in Economics, Politics, and Engineering and in Economics, Politics, and Science combine basic training in either engineering or science with the social sciences. This combination emphasizes the relationships among scientific, engineering, economic, political, and human relations problems, thus giving insight into both the technical and nontechnical aspects of an industrial society. Students may prepare for a wide range of careers, particularly in the research, engineering, economics, personnel, sales, production, and international departments of business and in governmental and labor organizations.

Students concentrating in political science will be equipped with knowledge and skills for dealing with the increasing range of problems which arise between business and government and which involve the activities of governmental agencies and political groups in matters of direct concern to scientists and engineers. The Courses also provide a broad undergraduate preparation for graduate work in such fields as economics, engineering, science, business administration, law, and medicine.

Students in Course XIV-A elect an area of engineering concentration which corresponds to one of the established engineering fields at M.I.T. Each student works out an individual program of studies which includes the core subjects required of those majoring in that engineering field, as recommended by the particular engineering department. Social science subjects are substituted for the more specialized subjects offered in the engineering Courses.

Similarly, students in Course XIV-B choose an area of science concentration. The same principle applies here, with the appropriate science subjects recommended by the science department concerned.

Course XIV-A leads to the degree of Bachelor of Science in Economics, Politics, and Engineering, and Course XIV-B leads to the degree of Bachelor of Science in Economics, Politics, and Science.

ECONOMICS

The objectives of the economics program are threefold: (1) to develop the ability to analyze, both theoretically and quantitatively, economic problems of the firm, the industry, and the economy as a whole; (2) to provide knowledge and understanding of economic and social institutions; and (3) to promote skill in examining broad questions of social and economic policy. The required subjects, while emphasizing the analytic side, provide a general background in the other two areas. The extent to which these various objectives are emphasized is then determined primarily by the student's selection of electives.

The elementary subjects, ECONOMIC PRINCIPLES I and II (14.01 and 14.02), are an introduction to the whole field of economics. The intermediate subjects, PRICES AND PRODUCTION (14.03) and ECONOMIC FLUCTUATIONS AND GROWTH (14.05), deepen this knowledge: the first in industry analysis and price formation, and the second in the study of economic fluctuations and growth. The quantitative side of economics is stressed in ELEMENTARY STATISTICAL ANALYSIS (14.31) and in STRUCTURE OF THE AMERICAN ECONOMY (14.06).

With this general background the student may go farther in particular fields by his choice of junior and senior electives. The program specifies that a minimum of five subjects (40

units) are to be elected in economics, with at least four of these subjects in one of three areas: (1) the general problems of an economy; (2) the particular problems of different industries and of labor relations; or (3) the more technical field of quantitative analysis, with further study in mathematics, statistics, and econometrics. If a student wishes, he also may elect up to four additional subjects in economics, two of which may be considered as electives in his humanities and social science elective program.

In the senior year, training in the methods of economic research is provided by participation in an ECONOMICS RESEARCH SEMINAR (14.39) in the first term, and by the writing of a thesis in the second.

The curriculum requirements for the Bachelor's degree under the Economics Program are given below.

1. ECONOMICS PROGRAM CURRICULUM				*Total units*
GENERAL INSTITUTE REQUIREMENTS (*see page 132*)				176
PHYSICS 8.03 and 8.04 are normally taken. If work in nuclear and atomic physics is to form part of a student's program in a science or engineering field, 8.031 and 8.041[1] are taken. Sixteen of the 32 units of humanities and social science electives must fall outside the field of a student's social science specialization. The remainder may form part of the concentration in economics.				
DEPARTMENTAL PROGRAM				
Required subjects				
14.01	ECONOMIC PRINCIPLES I	3	0 5	
14.02	ECONOMIC PRINCIPLES II	3	0 5	
14.03	PRICES AND PRODUCTION	3	0 5	
14.05	ECONOMIC FLUCTUATIONS AND GROWTH	3	0 5	
14.06	STRUCTURE OF THE AMERICAN ECONOMY	3	0 5	
14.31	ELEMENTARY STATISTICAL ANALYSIS	3	0 5	
14.39	ECONOMIC RESEARCH SEMINAR	2	0 6	
	THESIS		9	
				65
Elective subjects				
Specified				
Subjects in a particular field of engineering or science			63	
Economics elective subjects, with stipulation of a minimum of 32 units in one of the following areas: general economics, industrial and labor economics, or quantitative economics and method			40	
Unspecified			16	
				119
Total units required for the S.B. degree				360

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

POLITICAL SCIENCE

The political science programs give special attention to the growing interrelationship between government on the one hand and science and engineering on the other. The objectives are: (1) to provide an understanding of the nature of political behavior and the political process; (2) to examine government's role in science and technology, both in America and abroad, and its role in international relations; (3) to develop familiarity with the techniques of policy formulation and decision-making on issues of public policy.

There is no rigid program of subjects of instruction in the political science curriculum. Programs are worked out with the aid of an adviser. A student normally takes three or four subjects in some field that interests him particularly and one or two subjects in several other fields. One field, for example, is international relations, in which the introductory subject, INTERNATIONAL RELATIONS (14.51), is followed by a subject in PRINCIPLES AND PROBLEMS OF AMERICAN DIPLOMACY (14.52) and a SEMINAR IN INTERNATIONAL POLITICS (14.53). A comparative government field includes, among other subjects, THE AMERICAN POLITICAL PROCESS (14.91), COMPARATIVE POLITICAL SYSTEMS (14.92), and a SEMINAR: ISSUES IN CONTEMPORARY AMERICAN POLITICS (14.93). In the field of public policy, subjects include POLITICS, SOCIETY, AND POLICY MAKING (14.95); GOVERNMENT, POLITICS, AND TECHNOLOGY (14.94); and a triple subject, STRUCTURE OF URBAN LIFE (14.99). Another field covers political philosophy. Some of the subjects in this field are offered under the Department of Humanities but are fully accepted as political science subjects. Political philosophy subjects include CONTEMPORARY IDEAS ON POLITICAL AND ECONOMIC DEVELOPMENT (14.57), HISTORY OF POLITICAL AND SOCIAL THOUGHT (21.77), and POLITICAL AND SOCIAL PHILOSOPHY (21.78).

As a student progresses into his senior year and desires a higher degree of specialization than is offered in the available undergraduate subjects, he typically takes, in addition to his thesis work, some reading seminars and some graduate subjects from the political science offering.

The curriculum requirements for the Bachelor's degree under the Political Science Program are given below.

2. POLITICAL SCIENCE PROGRAM CURRICULUM	*Total units*
GENERAL INSTITUTE REQUIREMENTS (*see page 132*)	176
PHYSICS 8.03 and 8.04 are normally taken. If work in nuclear and atomic physics is to form part of a student's program in a science or engineering field, 8.031 and 8.041[1] are taken. Sixteen of the 32 units of humanities and social science electives must fall outside the field of a student's social science specialization. The remainder may form part of the concentration in politics.	

DEPARTMENTAL PROGRAM

Required subjects		
THESIS	9	
		9
Elective subjects		
Specified		
Elective subjects in a particular field of engineering or science	63	
Political science elective subjects	88	
Unspecified	24	
		175
Total units required for the S.B. degree		360

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

GRADUATE STUDY IN ECONOMICS AND POLITICAL SCIENCE

The Department of Economics and Social Science offers work leading to the degrees of Master of Science in Economics and Engineering, Master of Science in Economics and Science, Doctor of Philosophy in Industrial Economics, and Doctor of Philosophy in Political Science.

The following subjects are given by the Department primarily for graduate students in economics:

Economic theory:
14.121, 14.122, 14.123, 14.132, 14.151, 14.451, 14.452.

Economic history:
14.161, 14.162.

Monetary and Fiscal Economics:
14.461, 14.471, 14.472.

Economic development:
14.171, 14.172, 14.182.

Industrial organization and policy:
14.271, 14.272.

Economics of innovation:
14.281, 14.282.

Statistics:
14.371, 14.372, 14.374, 14.383, 14.384.

International economics:
14.581, 14.582, 14.584.

Labor economics and public policy:
14.671, 14.672, 14.674, 14.691, 14.692.

Personnel administration:
14.681, 14.682, 14.693, 14.774, 15.312.

Human relations in industry:
14.774, 15.362, 15.373.

Special subjects:
14.101 (for students with little or no college mathematics).
14.381 (for students with little or no previous statistics).

Special reading subjects:
Students may arrange with individual instructors to take special reading subjects in fields of their particular interest which are not otherwise covered.

The following subjects are given by the Political Science Section primarily for graduate students in political science and related fields:

International relations and foreign policy:
14.531, 14.532, 14.534, 14.535.

Political communications:
14.951, 14.953, 14.954, 14.956, 14.957, 14.958, 14.961, 14.962.

Defense policy:
14.521, 14.523, 14.524, 14.526.

Public policy and science:
14.941, 14.942, 14.943, 14.944.

Political and economic development:
4.84, 14.161, 14.162, 14.585, 14.921, 14.924, 14.925.

Political theory and comparative politics:
14.57, 14.58, 14.901, 14.902, 14.922, 14.926.

Special reading subjects:
Students may arrange with individual instructors to take special reading subjects in fields of their particular interest which are not otherwise covered.

MASTER OF SCIENCE IN ECONOMICS AND ENGINEERING OR IN ECONOMICS AND SCIENCE

Undergraduate preparation for the Master's degrees should include the equivalent of the Institute's economics subjects required for the Bachelor's degree. The other admission requirements are those given in Section 3 of this Catalogue, with the following exceptions:

Mathematics. DIFFERENTIAL EQUATIONS (18.04) is not a prerequisite.

Physics. A complete college course in physics of at least *one* year is required.

Science and Engineering Subjects. A substantial number of science or engineering units is required, comparable to the number required in the undergraduate Course XIV. The Master's degree is available only to students who have taken a substantial amount of undergraduate work in engineering or science.

Students who have deficiencies in prerequisites for admission may take these prerequisites along with their graduate work.

Graduates of Course XIV-A or XIV-B or of similar undergraduate programs elsewhere ordinarily complete the requirements for the Master's degree in one year. Candidates with an undergraduate major in engineering or science elect a two-year program. The first year of study is devoted to satisfying economics prerequisites, and the second year is given completely to graduate work, in accordance with the general requirements for the Master's degree.

Doctoral Studies in Economics or Political Science

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites for graduate study leading to the Doctor of Philosophy in Industrial Economics or in Political Science:

Mathematics. One full year of college mathematics, including at least one term of calculus.
Science. One full year of college work in science.
Humanities. At least six semester subjects in English, history, and other humanities subjects equivalent in scope to those included in undergraduate humanities curricula of the Institute.
Professional Subjects. See the separate requirements for economics and political science below.

Economics students may remove a deficiency in mathematics by completing a special one-semester subject, MATHEMATICS FOR ECONOMISTS (14.101). Political science students may remove a deficiency in mathematics by completing a special one-semester subject, INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (14.903), and one other semester of mathematics in such subjects as MATHEMATICS FOR ECONOMISTS (14.101 or 14.102) or STATISTICAL METHOD (14.381). A deficiency in science may be removed by completing any suitable one-semester subject in science at the Institute. A student whose deficiencies are of minor extent will be permitted graduate registration while taking appropriate subjects to remove them.

DOCTOR OF PHILOSOPHY IN INDUSTRIAL ECONOMICS

Ordinarily, an undergraduate major in economics is required for doctoral studies in industrial economics. However, qualified students who have majored in a related field may be admitted if their programs have included an appreciable amount of economics.

A candidate for the doctorate must prepare himself in five fields, four of which are covered by the General Examination. Economic theory, including both micro- and macroeconomics, is required as a primary field for all students. One other field, also designated as primary, requires more intensive preparation than the remaining three, which are designated as secondary. Elective fields include advanced economic theory, monetary and fiscal economics, industrial organization and policy, economics of innovation, international economics, economic development, labor economics and labor relations, human relations in industry, personnel administration, economic history, statistical theory and methods, and others. If statistics and economic history are not among the candidate's five fields of concentration, he must also take one graduate subject in each of these areas.

Following the Institute rules, candidates for the doctorate are required to take a Minor in a field other than economics. Possibilities include political science and international relations, industrial management, mathematics, history, other humanities or social sciences, and particular fields of science or engineering.

DOCTOR OF PHILOSOPHY IN POLITICAL SCIENCE

A candidate for the doctorate in political science must prepare himself for a General Examination covering four approved fields. In studying for this examination, he must satisfy a basic requirement in two subjects: CONCEPT FORMATION AND RESEARCH TECHNIQUE IN POLITICAL BEHAVIOR (14.901) and THEORY OF POLITICAL PROCESSES (14.902). Possible fields include: international relations and foreign policy, political communications, defense policy, public policy and science, political and economic development, and political theory and comparative politics; or approved combinations of some of these together with economics, industrial management, sociology, social psychology, or science and engineering fields may be acceptable.

Programs of study logically combining advanced work in some scientific or engineering fields with political science will be welcomed. 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.

Following the Institute rules, candidates for the doctorate will be required to take a Minor in a field other than political science. Possibilities include economics, industrial relations, industrial management, mathematics, history, philosophy, sociology, social psychology, or relevant fields in science or engineering.

General Requirements for Doctoral Candidates

No stated number of graduate subjects in the Department of Economics and Social Science are required, but ordinarily the candidate will need two full academic years of work to prepare himself adequately for his General Examination and to meet the other pre-thesis requirements.

The doctoral thesis must be written in residence. As a rule it represents one year's research.

Candidates are required to demonstrate their ability to read professional literature in two modern foreign languages. These languages will ordinarily be chosen from German, French, or Russian; however, other languages may be substituted when they have sufficient professional significance for the individual candidate.

Department of Humanities

HOWARD RUSSELL BARTLETT, B.S., A.M.
Professor of English and History; Head of the Department

JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities; Dean of the School of Humanities and Social Science

WILLIAM CHACE GREENE, M.A. (*Absent*)
Professor of English; Assistant Secretary of the Faculty

GIORGIO DIAZ DE SANTILLANA, PH.D.
Professor of the History and Philosophy of Science

CARVEL COLLINS, PH.D. (*Absent*)
Professor of English

KLAUS LIEPMANN
Professor of Music; Director of Music

ROY LAMSON, PH.D.
Professor of English

HUSTON CUMMINGS SMITH, PH.D.
Professor of Philosophy

JOHN BARDLEY RAWLS, PH.D.
Professor of Philosophy

CYRIL STANLEY SMITH, SC.D.
Institute Professor; Professor of the History of Science and Technology

ROBERT STONE COHEN, PH.D.
Professor of the Philosophy of Science (Visiting)

THOMAS HENRY DONALD MAHONEY, PH.D. (*Absent*)
Professor of History

THEODORE RUSSELL WEISS, M.A.
Professor of English (Visiting)

LYNWOOD SILVESTER BRYANT, A.M.
Associate Professor of History; Director of the M.I.T. Press

THEODORE WOOD, JR., S.B., A.M.
Associate Professor of English

EDWARD NEAL HARTLEY, A.M.
Associate Professor of History

ROBERT REYNOLDS RATHBONE, A.M.
Associate Professor of English

ALFRED DUPONT CHANDLER, JR., PH.D.
Associate Professor of History

IRVING SINGER, PH.D. (*Absent*)
Associate Professor of Philosophy

GREGORY TUCKER
Associate Professor of Music

ROBERT SMITH WOODBURY, S.B., A.M.
Associate Professor of the History of Technology

ROBERT ELLSWORTH MACMASTER, PH.D.
Associate Professor of History

HARALD ANTON THRAP OLSEN REICHE, PH.D.
Associate Professor of Classics and Philosophy

BRUCE MAZLISH, PH.D.
Associate Professor of History

WALTER FRANCIS URBACH, A.M.
Assistant Professor of English

NORMAN NORWOOD HOLLAND, PH.D.
Assistant Professor of English

CHARLES FENNO HOFFMAN, JR., PH.D.
Assistant Professor of English

CHARLES ROBERT NIEHAUS, PH.D.
Assistant Professor of History

GORDON MAURICE JENSEN, PH.D.
Assistant Professor of History

HAROLD CLARK KIRKER, PH.D. (*Absent*)
Assistant Professor of History

RICHARD LEE SCHOENWALD, PH.D.
Assistant Professor of History

HUMANITIES

DEPARTMENT OF HUMANITIES

ABNER ELIEZER SHIMONY, PH.D. (*Absent*)
Assistant Professor of the Philosophy of Science
EMMET JOSEPH LARKIN, PH.D.
Assistant Professor of English
JAMES BLAINE STONE, A.B.
Assistant Professor of English
LAWRENCE WHITCOMB BARSS, PH.D.
Assistant Professor of History
LOUIS KAMPF, PH.D.
Assistant Professor of English
VICTOR HENRY MATTFELD, PH.D.
Assistant Professor of Music; Organist
THOMAS WHIPPLE PERRY, PH.D.
Assistant Professor of History

Lecturer

JOSEPH DEE EVERINGHAM, A.M.,
Director of Drama

Instructors

SAMUEL JUDAH TODES, M.A.
WILLIAM HARVEY YOUNGREN, PH.D.
HUBERT LEDERER DREYFUS, A.M.
PETER HENRY ELBOW, B.A.
IRA ALBERT GLAZIER, M.A.
MORTON GORDEN, A.M.
ALBERT R. GURNEY, M.F.A.
ROBERT CARL SHIPKEY, M.A.
BARRY BERNARD SPACKS, M.A.
OWEN PHILIP STEARNS, M.A.
MELVIN JAY TUCKER, M.A.
WILLIAM BRAASCH WATSON, A.M.
ROBERT ADOLPH, A.M.
ROBERT SHENTON, M.B.A.
RICHARD FRED SMITH, B.S.
THOMAS NATHANIEL TENTLER, A.M.

HUMANITIES

M.I.T., in its determination to achieve a well-balanced education for all its undergraduates, provides through this Department required and elective subjects in history, literature, philosophy, history and philosophy of science, music, and drama.

In addition, the Department of Humanities administers two Courses. These combine the basic subjects in science or engineering with a concentrated program in the humanities, in nearly equal proportions. They are known as Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B).

THE UNDERGRADUATE CURRICULA

Humanities and Engineering (Course XXI-A)
Humanities and Science (Course XXI-B)

The broad objective of the Courses in Humanities and Engineering and in Humanities and Science is to provide a four-year general education rooted in science or engineering or a five-year professional education combined with a general education. These Courses are further designed to prepare students for graduate study in science, engineering, medicine, law, business, public administration, education, and in major fields of the humanities. Because of a flexible program of elective subjects, especially in the third and fourth years, a student may devote about half of his studies to humanities and the remainder to science or engineering, developing special interests in any combination of these fields.

Both Courses award a Bachelor's degree after four years; a student may study a fifth year to earn a second Bachelor's degree in the particular field of science or engineering he has been exploring; in some cases this fifth year may lead to a Master's degree.

On a base which is essentially the Institute's well-rounded program of introductory mathematics, physics, chemistry, and humanities, each of these Courses provides a balanced educational experience. One part of each program is the undergraduate curriculum of one of the professional departments, shortened through omission of some of the more specialized or technical subjects. The other is a sequence of advanced work in humanities, concentrating in one particular humanities discipline of the student's choice: literature and the arts, history, philosophy, or the history and philosophy of science. This concentration in the humanities begins with two basic subjects in the area elected for study, such as: INTRODUCTION TO LITERATURE and LITERARY CRITICISM (21.11 and 21.12); or

THE UNITED STATES: MAKING OF A NATION, 1760–1865 and THE UNITED STATES: INDUSTRIAL AND WORLD POWER, 1865–1960 (21.41 and 21.42); or MODERN EUROPE, 1500–1815 and MODERN EUROPE, 1815–1960 (21.51 and 21.52); or PHILOSOPHICAL PROBLEMS AND SYSTEMS I and II (21.61 and 21.62); or SCIENCE AND PHILOSOPHY FROM ANTIQUITY TO COPERNICUS and SCIENCE AND PHILOSOPHY FROM COPERNICUS TO THE PRESENT (21.81 and 21.82).

To assist students in integrating their studies and in bringing into focus the insights and techniques developed in both professional and humanistic studies, the Department makes two requirements: the senior HUMANITIES SEMINAR (21.05 and 21.06); and the writing of a thesis.

Course XXI-A leads to the degree of Bachelor of Science in Humanities and Engineering, and Course XXI-B leads to the degree of Bachelor of Science in Humanities and Science. The curriculum for the first year is shown on pages 38–39; the curriculum requirements for the degrees in both Courses are summarized below.

			Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 132*)			**176**
	PHYSICS 8.03 and 8.04 or 8.031 and 8.041[1] are taken according to the science or engineering curriculum being pursued in conjunction with humanities.		
DEPARTMENTAL PROGRAM			
	Required subjects		
21.05	HUMANITIES SENIOR SEMINAR	3 0 6	
21.06	HUMANITIES SENIOR SEMINAR	1 0 4	
	THESIS	12	
			26
	Elective subjects		
	Specified		
	Basic subjects in the humanities discipline chosen for concentration	16	
	Elective subjects restricted to one of the science or engineering curricula	52[2]	
	Elective subjects restricted to one of the humanities disciplines: e.g., literature, philosophy, etc.	32	
	Unspecified	58	
			158
Total units required for the S.B. degree			**360**

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).
[2] The student who intends to obtain a second S.B. degree in one of the science or engineering Courses by continuing his studies at M.I.T. in a fifth year and the student who plans to enter upon graduate study in science or engineering will have to carry at least 88 units. The additional units will be drawn from the 58 units of unrestricted elective subjects.

Science and Mathematics Teaching Program

Students who wish to register for the Science and Mathematics Teaching Program conducted in cooperation with the Harvard University Graduate School of Education should consult the Head of the Department of Humanities.

Department of Modern Languages

WILLIAM NASH LOCKE, PH.D.
Professor of Modern Languages; Head of the Department
ROMAN JAKOBSON, PH.D.
Institute Professor
WILLIAM FILBERT BOTTIGLIA, PH.D.
Professor of Modern Languages
NOAM AVRAM CHOMSKY, PH.D.
Professor of Modern Languages
MORRIS HALLE, PH.D.
Professor of Modern Languages
RICHARD FELIX KOCH, A.M.
Assistant Professor of Modern Languages, Emeritus; Lecturer
SECOR DELAHAY BROWNE, A.B.
Assistant Professor of Russian
EDWARD STEPHEN KLIMA, M.A.
Assistant Professor of Modern Languages
ALEXANDER LOUIS LIPSON, A.M.
Assistant Professor of Russian
ANTHONY MATTHEW MLIKOTIN, PH.D.
Assistant Professor of Modern Languages
STEPHEN JULES GENDZIER, PH.D.
Assistant Professor of Modern Languages

Lecturers
PRIMUS BENEDICT BON, B.S., M.A.
ELENA CAFFREY, M.A., M.S.
MARGARET ZAROODNY FREEMAN, S.M.

Instructors
SUMNER KIRSHNER, M.A.
DAVID ALLEN DINNEEN, M.A. (*Absent*)
PAUL MARCEL HOHENBERG, B.CH.E., M.A.
RENATA ANITA BRIGGS-HOFMAN
RAYMONDE DALLAIRE, M.A.
DAVID MICHAEL PERLMUTTER, A.B.
GUNTER FAURE, PH.D.

Research Associate
G. HUBERT MATTHEWS, PH.D.

Professors Emeriti
RICHARD FELIX KOCH, A.M.
Assistant Professor of Modern Languages, Emeritus; Lecturer
GEORGE ALEXANDROVICH ZNAMENSKY, B.D., ED.M.
Assistant Professor of Russian, Emeritus
HERMAN KLUGMAN, PH.D.
Assistant Professor of Modern Languages, Emeritus

The Modern Language Department offers subjects on the undergraduate and graduate levels in German, French, and Russian. It also provides a program leading to the degree of Doctor of Philosophy in Linguistics.

Undergraduate Subjects

The Department provides instruction on several levels in German, French, and Russian. Introductory subjects aim first at familiarity with the spoken language, emphasizing pronunciation, and second at minimum essentials for a reading knowledge. The intermediate level provides for a continuation of speaking and the development of a broad reading vocabulary. The texts cover fiction, drama, and historical or descriptive works to introduce students to the genius, institutions, and social organization of the countries in question. Advanced subjects are conducted entirely in the foreign language and include discussions of the form and content of the literature of each country. A specially equipped language laboratory provides facilities for hearing and speaking languages at all levels.

Undergraduate subjects in linguistics are offered to explore the structural and semantic relationships of language and to examine problems in linguistics and search for possible solutions. There is an active program of research, in which tools and concepts of science and engineering are applied to the study of language.

Special sections of the freshman and sophomore humanities subjects (21.01, 21.02, 21.03, and 21.04) provide reading and lectures in French, allowing students to use and improve their knowledge of the language while simultaneously satisfying the humanities requirement. These sections are open to graduates of American high and secondary schools with three or more years of unusually good achievement in French. A special section of INTRODUCTORY CIRCUIT THEORY I and II (6.01, 6.02) is also conducted in French.

The Department's subjects are open as electives to all qualified students throughout the Institute and are acceptable as freshman electives. There is, however, no undergraduate degree program in modern languages or linguistics at M.I.T.

In choosing language subjects, students should assume that one year of secondary school study is roughly equivalent to one Institute term. Credit towards graduation will not be given for repeating work offered for admission.

Graduate Subjects

One-semester subjects in French, German, and Russian, *open to graduate students only*, are designed to help each student develop rapidly the ability to read technical and scientific material in his own field whether or not he has any previous acquaintance with the language. These subjects carry no credit.

The Doctoral Program in Modern Languages (Course XXIII)

The program of studies leading to the degree of Doctor of Philosophy in Linguistics aims to give a comprehensive knowledge of modern linguistics, with particular emphasis on its experimental, quantitative, and theoretical aspects. To enter the program, each student must satisfy the Institute requirements for admission to the Graduate School and have done well in his previous academic work. He must be formally accepted by the Department of Modern Languages as a candidate for the degree.

DOCTOR OF PHILOSOPHY IN LINGUISTICS

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites:

Mathematics. One full year of college mathematics is required.

Science. One full year of college work in science is required.

Languages. Competence in two languages in addition to English is required, competence being defined as at least three years of formal study or the equivalent.

Humanities. At least six semester subjects in literature, history, philosophy, or other humanities subjects equivalent in scope to those included in the undergraduate humanities curricula of the Institute, are required.

A student with high academic rating who is deficient to a minor extent in one or more of the above requirements may be permitted graduate registration while fulfilling them at the Institute by taking appropriate subjects.

Subjects required of all doctoral candidates are as follows:

STRUCTURE OF ENGLISH (23.731)
PROBLEMS OF PHONOLOGY (23.761)
SURVEY OF GENERAL LINGUISTICS (23.781)
LINGUISTIC STRUCTURE (23.782)
RESEARCH SEMINAR

Before the student may start his doctoral research he is required to pass a comprehensive General Examination demonstrating competence in general linguistics, linguistic theories and methods, practical linguistic analysis, and the relation between linguistics and some adjacent field such as electrical engineering, mathematics, philosophy, physics, or psychology.

A Minor in one of the above related fields is recommended, though many other fields may also be suitable. The general Institute policies concerning the Minor program, examinations, and the thesis is given in Section 3 of this Catalogue.



SCHOOL OF INDUSTRIAL MANAGEMENT 8.

The Dean of M.I.T.'s newest School describes its origins and present objectives.

The preparation of managers has long been an appropriate and significant responsibility for M.I.T. Management is concerned with the *action* that effectively integrates the technological, economic, and human resources to meet the goals of an organization. As the "oldest of the arts and the newest of the professions," management is an applied field, and the manager leans heavily on the contributions of the social and physical sciences and the humanities in meeting the problems of industry, community, and government. He makes his decisions, moreover, in a society characterized by increasingly complex technology. For the man who seeks to master the practice of management and for the researcher who wants to understand it better, the Institute provides a focus of these factors and frameworks.

The concept of combining scientific and engineering education with a preparation for management at M.I.T. dates formally to 1914 with the founding of a four-year undergraduate Course. In 1952, the School of Industrial Management was established by a grant of the Alfred P. Sloan Foundation. Today, unique among schools preparing men for management, the School has a student body which includes four levels of students who work together, each benefiting from associations with the others: the undergraduates, seeing management problems for the first time while following an intensive parallel program in one field of science or engineering; the graduate students, including both master's and doctoral candidates in industrial management; participants in the Sloan Fellowship Program for young executives about to assume major responsibilities; and members of the Program for Senior Executives, who have advanced experience and responsibilities.

For all these groups, the general approach to education for management in the School of Industrial Management remains one of emphasis on a firm grasp of fundamental frameworks of analysis, a breadth of view, and a habit of continued learning that bring a confident and competent approach to problems yet unsolved in industry. Three points indicate the basis of this approach.

First emphasis is put on study of the role of man himself. Here is included the full sweep of the organizational relationships between men and groups in achieving their objectives. Here also is the study in depth of the environment within which business must progress. The economy and its complex effects on the individual firm, the social and political world, and, indeed, a sense of the history of change and progress must be part of the manager's understanding.

Second, a strong point in the School's approach to managerial education has always been in the measurement and quantitative analysis of management

problems. While management is an art, it is an art that is immensely and importantly influenced by the application of the methods of science to its many complex, interrelated elements. The student who is to be the senior manager of the future must be well grounded in the mathematical analyses of operations, in the methods of management decision-making made possible by high-speed computers, and in the more rigorous control applications of accounting, statistics, and forecasting.

Third is the attack on practical problems which represent a complex mixture of several variables. These are traditionally represented under such headings as marketing, production, and finance. In this functional area approach, theory is applied to practical studies of problems now existing and constantly arising in a world of action.

These three areas form a base for the analytical approach to managerial education and the ground for intensive research into the problems of the future manager. HOWARD W. JOHNSON

HOWARD WESLEY JOHNSON, M.A.
Professor of Industrial Management; Dean

DOUGLASS VINCENT BROWN, PH.D.
Alfred P. Sloan Professor of Industrial Management

DOUGLAS MURRAY McGREGOR, PH.D., LL.D.
Professor of Industrial Management

EDWARD PENNELL BROOKS, D.S.C.
Professor of Industrial Management, Emeritus; Lecturer; Dean Emeritus

ELI SHAPIRO, PH.D.
Professor of Finance

ELTING ELMORE MORISON, A.M.
Professor of Industrial History

BILLY EARL GOETZ, PH.D.
Professor of Industrial Management

HOULDER HUDGINS, B.A.
Professor of Industrial Management

SIDNEY STUART ALEXANDER, PH.D. (*Absent*)
Professor of Industrial Management

JAY WRIGHT FORRESTER, D.ENG.
Professor of Industrial Management

DAVID DURAND, PH.D.
Professor of Industrial Management

DONALD GEORGE MARQUIS, PH.D.
Professor of Industrial Management

CARROLL LOUIS WILSON, SC.D.
Professor of Industrial Management

EDWARD LINDLEY BOWLES, D.SC.
Professor of Industrial Management (Consulting)

BERNARD J. MULLER-THYM, PH.D., LL.D.
Professor of Industrial Management (Visiting)

ROBERT L. DIXON, PH.D.
Professor of Industrial Management (Visiting)

RALPH SAMUEL ALEXANDER, PH.D.
Professor of Industrial Management (Visiting)

ROSS MACDUFFEE CUNNINGHAM, D.C.S.
Associate Professor of Marketing

GERALD BRUCE TALLMAN, PH.D.
Associate Professor of Marketing

THOMAS MASON HILL, A.B., M.B.A. (*Absent*)
Associate Professor of Industrial Management

MYRON JULES GORDON, PH.D.
Associate Professor of Industrial Management

LEO BENJAMIN MOORE, S.M.
Associate Professor of Industrial Management

DANIEL MARK HOLLAND, PH.D.
Associate Professor of Finance

WILLIAM LOUIS LETWIN, PH.D.
Associate Professor of Industrial History

WARREN G. BENNIS, PH.D. (*Absent*)
Associate Professor of Industrial Management
EDWARD HARRY BOWMAN, PH.D.
Associate Professor of Industrial Management
STANLEY MARTIN JACKS, A.M., LL.B.
Associate Professor of Industrial Management
EDWIN KUH, PH.D. (*Absent*)
Associate Professor of Finance
EDGAR HENRY SCHEIN, PH.D.
Associate Professor of Industrial Management
MARTIN GREENBERGER, PH.D.
Associate Professor of Industrial Management
ZENON SOTERIOU ZANNETOS, PH.D.
Associate Professor of Industrial Management
WILLIAM A. WALLACE KREBS, JR., A.B., LL.B.
Associate Professor of Law (Visiting)
HARRY LEVINSON, PH.D.
Associate Professor of Industrial Management (Visiting)
MARTIN SEGAL, PH.D.
Associate Professor of Industrial Management (Visiting)
HERBERT FRANKLIN GOODWIN, S.B.
Assistant Professor of Industrial Management
RICHARD BLAISE MAFFEI, PH.D.
Assistant Professor of Industrial Management
CHADWICK JOHN HABERSTROH, PH.D.
Assistant Professor of Industrial Management
THOMAS MARTIN LODAHL, PH.D.
Assistant Professor of Industrial Management
PAUL HAROLD COOTNER, PH.D.
Assistant Professor of Finance
JAMES CARLETON EMERY, S.M.
Assistant Professor of Industrial Management
WILLIAM FRANCIS MASSY, PH.D.
Assistant Professor of Industrial Management
JOHN DAVID BOSSONS, A.M.
Assistant Professor of Finance
DONALD CARY CARROLL, S.M.
Assistant Professor of Industrial Management
GEOFFREY P. E. CLARKSON, PH.D. (*Absent*)
Assistant Professor of Industrial Management
HENRY JOHN CLAYCAMP, JR., PH.D.
Assistant Professor of Industrial Management
STUART ERNEST DREYFUS, A.B.
Assistant Professor of Industrial Management
MYLES M. DRYDEN, PH.D.
Assistant Professor of Finance
RONALD ARTHUR HOWARD, SC.D.
Assistant Professor of Industrial Management
WILLIAM F. POUNDS, M.S.
Assistant Professor of Industrial Management
BARNARD ELLIOTT SMITH, PH.D.
Assistant Professor of Industrial Management
ANDREW CHARLES STEDRY, PH.D.
Assistant Professor of Industrial Management
WILLIAM PENFIELD TRAVIS, M.A.
Assistant Professor of Industrial History
PEER OLAV SOELBERG, PH.D.
Assistant Professor of Industrial Management

Lecturers

JAMES CHRISTIAN ABEGGLEN, PH.D.
DAVID FERGUESON AUSTIN, LL.D.
JOHN PAUL EBERHARD, S.M.
STUART MACMILLAN, PH.B., LL.B.
RICHARD THOMAS MURPHY, JR., A.B., B.S., LL.B.

Instructors

THEODORE MARK ALFRED, A.B., M.B.A.
EDWARD BAER ROBERTS, S.M.
CHARLES HARRY SCHREIBER, JR., S.B., M.B.A.
MICHAEL JAMES BROWER, B.S., M.A.

Executive Development Programs

JOHN MACDONALD WYNNE, A.B., S.M.
Director
JAMES BRUCE NEIGHBOR, M.A.
Assistant Director

Sloan Teaching Interns

ARTHUR JAMES BONESS, M.A.
CURTIS HARVEY JONES, A.B., M.B.A.
ERNEST ANTHONY LOWE, B.S.
JAMES BUREN LUDTKE, PH.D.
BERNT PETTER STIGUM, M.A.
RICHARD DEANE TERRELL, B.S.

Research Associates

ARNOLD EVERETT AMSTUTZ, S.B.
JOHN DANIEL NYHART, A.B., LL.B.
ALEXANDER LE FEVRE PUGH, III, E.E.

Administrative Assistants

GERTRUDE ELIZABETH BURNS
ESTHER MERRILL, B.S.
MIRIAM SHERBURNE, A.B.

Professors Emeriti

ERWIN HASKELL SCHELL, S.B.
Professor of Industrial Management, Emeritus
CHARLES HUNTINGTON PORTER, A.B., S.B.
Professor of Accounting, Emeritus
EDWARD PENNELL BROOKS, D.S.C.
Professor of Industrial Management, Emeritus; Lecturer; Dean Emeritus

THE UNDERGRADUATE CURRICULUM

Industrial Management (Course XV)

The undergraduate Course in Industrial Management is designed especially for students who combine an aptitude for science and engineering with the qualities necessary for effective administration. Successful management of industrial enterprises in the future will demand the ability to deal with technological problems of increasing complexity, a broad comprehension of business problems, and a deep understanding of human behavior. Fundamental training in science and engineering has proved to be an excellent base for the study of management, and the Institute is uniquely qualified to provide a curriculum which combines science and technology with administration and the humanities.

The undergraduate program in Industrial Management rests upon the underlying disciplines of the social sciences, especially economics. Students who plan to study management should anticipate their future work by taking a basic subject in economics during their sophomore year. This provides the foundation for prescribed subjects in advanced economics, accounting, finance, marketing, and personnel administration. In all of these subjects, the emphasis is on the application of the social sciences to the analysis of business problems and the understanding of managerial principles.

Much of the work in management is quantitative, and several of the prescribed subjects offer an immediate introduction to the use of the many rapidly developing mathematical and statistical techniques for solving industrial problems.

The management curriculum provides for flexibility by allowing five or six electives, about half of which would ordinarily be taken in management or related subjects.

An important part of the fourth-year program is the thesis, which affords the dual opportunity of exploring in depth a problem of the student's own choice and of carrying out a limited research program on his own initiative.

The science and engineering programs in the Course in Industrial Management emphasize matter of a fundamental nature rather than the details of its application. The School believes that within the limits of a four-year program, of which the main objective is a sound professional education for administration, students should have a solid foundation in science and engineering subjects — first, as a preparation for effective management and second, as a preparation for further progress in professional engineering. Although most students follow programs based on mechanical, electrical, or chemical engineering, a few follow sequences in mathematics, metallurgy, and geology, and programs in other fields may also be arranged.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course Schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities and social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

The curriculum leading to the degree of Bachelor of Science in Industrial Management consists of a program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) and a grouping of subjects which combine work in a field of engineering or science with the study of industrial management (the Departmental Program). The curriculum requirements for this degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS					
5.01	[1]GENERAL CHEMISTRY	4	2	5	
5.02	[1]GENERAL CHEMISTRY	4	2	5	
8.01	[1]PHYSICS	4	1	6	
8.02	[1]PHYSICS	4	1	6	
8.03	[2]PHYSICS				
or		4	1	5	
8.031	[2]PHYSICS				
8.04	[2]PHYSICS				
or		4	1	5	
8.041	[2]PHYSICS				
18.01	[1]CALCULUS	3	0	6	
18.02	[1]CALCULUS	3	0	6	
18.03	CALCULUS	3	0	6	
18.04	DIFFERENTIAL EQUATIONS	3	0	6	
21.01	[1]INTRODUCTION TO THE HUMANITIES	3	0	5	
21.02	[1]INTRODUCTION TO THE HUMANITIES	3	0	5	
21.03	MODERN WESTERN IDEAS AND VALUES	3	0	5	
21.04	MODERN WESTERN IDEAS AND VALUES	3	0	5	
	[1]*Freshman electives*			12	
	[3]*Humanities and social science electives*			32	
					176

A thesis or project is part of the General Institute Requirements. The required units of THESIS are given under the Departmental Program below.

DEPARTMENTAL PROGRAM					
	Required subjects				
15.01	INDUSTRIAL MANAGEMENT I	3	0	6	
15.02	INDUSTRIAL MANAGEMENT II	3	0	6	
15.30	PERSONNEL ADMINISTRATION	3	0	6	

(*continued*)

Departmental Program (continued)

15.41	FINANCIAL MANAGEMENT	3	0	6	
15.50	MANAGERIAL ACCOUNTING	2	3	4	
15.71	PRODUCTION MANAGEMENT	3	0	6	
15.81	MARKETING	3	0	6	
	THESIS		12		
					75
	Elective subjects				
	Specified				
	Subjects in science or engineering making up a program minimally totaling		72		
	Unspecified		48		
					120
	Total units required for the S.B. degree				[4]371

[1] Subjects of the common first-year program. See pages 38–39.

[2] PHYSICS 8.03 and 8.04 are taken except when plans for further work clearly indicate the need for the subject matter of 8.031 and 8.041; 8.041, if selected, must be followed by 8.051 (or 8.05).

[3] See pages 39–42 for the humanities and social science program. ECONOMIC PRINCIPLES I (14.01) is required. Subjects in Field Six (Economics) and Field Eight (Labor Relations) may not be used in satisfaction of the humanities and social science sequence requirement.

[4] In exceptional cases this total may be reduced by the School within the General Institute Requirements.

MANAGEMENT MINOR FOR ENGINEERS

In addition to the above, the School of Industrial Management offers upperclass undergraduates majoring in any field of engineering or science a program known as the Management Minor. This program consists of four basic core subjects plus two optional subjects. It is described in a brochure available through departmental Faculty Counselors or at the office of the Undergraduate Program in Industrial Management, Room 52-480.

GRADUATE STUDY IN INDUSTRIAL MANAGEMENT

The School of Industrial Management offers graduate study leading to the degrees of Master of Science and Doctor of Philosophy in Industrial Management.

MASTER OF SCIENCE

The Master's program is designed to prepare the science or engineering graduate for executive responsibilities — to develop men whose intelligence, motivation, and character promise executive ability and whose training and experience combine an understanding of natural science and engineering with an appreciation of the social, political, and economic implications of industry. Outstanding applicants whose undergraduate work has been in the humanities or social sciences will be considered for admission if the minimum prerequisites listed below have been met or can be satisfied after admission.

Although the primary aim is not that of training staff specialists, proposals for specialized programs will be considered when the desired course of study is particularly appropriate to the facilities available at M.I.T. Possible special programs include a concentration in subjects in industrial operations research and in business applications of electronic data-processing equipment.

The typical Master's degree program in industrial management requires two years of study at M.I.T. Credit for subjects completed elsewhere may permit some students to meet the requirements for the degree in three semesters or in one year. The first-year curriculum for those who have done no previous work in this field includes the following subjects:

STATISTICAL METHOD (15.025)
PROBLEMS IN AMERICAN POLITICAL ECONOMY (15.201)
SOCIAL PSYCHOLOGY (15.371)
MANAGERIAL ACCOUNTING (15.501T)
ECONOMICS OF THE FIRM (15.511)
ECONOMICS AND INDUSTRIAL MANAGEMENT (14.117)
LABOR-MANAGEMENT RELATIONS (15.312)
FINANCIAL MANAGEMENT (15.412T)
PRODUCTION MANAGEMENT (15.712)
MARKETING (15.812)

The second year is given wholly to advanced work, in accordance with the general requirements for the Master's degree. The typical program includes eight elective subjects and a thesis, the latter representing an individual research project conducted under the supervision of a separate staff committee for each student. Subject offerings are described elsewhere in this Catalogue. Selection is not limited to offerings in the School of Industrial Management.

Features of the graduate program include special seminars with visiting lecturers from industry, group field work, participation in faculty research, and individual field and laboratory investigation. The facilities of the M.I.T. Computation Center are available for use in testing models designed to aid in management decision-making. The Master's thesis usually involves intensive study of some industrial problem of significance to a participating company or to industry in general. Part-time research assistantships carrying substantial stipends and affording opportunity for direct participation in faculty research are available.

DOCTOR OF PHILOSOPHY

The doctoral program in industrial management is designed primarily for students interested in teaching and research in industrial management

and business administration or in the conduct of specialized managerial functions in business or other organizations. The program is largely an integration of the several fields which can advance the study and practice of management. It accordingly requires familiarity with a broad range of basic management subjects, reflected in a distribution requirement. It also requires specialization in at least one area of managerial application together with one or more of the underlying disciplines.

The doctoral program normally requires two years' work beyond the School of Industrial Management's requirement for a Master's degree, about one year of course work and another year for the doctoral thesis. A Master's degree is normally taken by Doctor's degree candidates. Each student's program, to be worked out with a specially designated faculty committee, is subject to four principal requirements: distribution, specialization, general examination, and thesis. In addition, students must fulfill the minor field and language requirements given in Section 3.

Distribution

A student must present evidence of his grasp of the ten subject areas required in the first year of M.I.T.'s program for the Master's degree in Industrial Management (see above). This evidence may be presented by acceptable graduate course credit, by examination, or by extensive undergraduate work with distinction.

Specialization

The candidate must offer, subject to approval by his committee, an area of specialization consisting of one applied area of management in combination with one or more primary disciplines, normally selected from the following list. The list is not exhaustive, however, and proposals for the inclusion of other studies in a doctoral program are considered.

Primary disciplines	*Areas of application*
Economics	Production
Psychology	Marketing
Quantitative analysis	Business finance
Statistics	Controllership and accounting
Operations research	Managerial organization
Mathematics	Labor relations — personnel
Industrial dynamics	International management
Political science	
Other social sciences	

General Examination

Upon prospective completion of the program of course work arranged with his committee, the student takes a general examination in four fields: his field of functional specialization, two fields in his primary discipline, and a fourth field selected with the approval of his committee as meaningfully related to his program.

Doctoral Thesis and Special Examination

The doctoral candidate's thesis, written in residence, normally represents a year's research. It must give evidence of the candidate's ability to design and carry out significant scholarly research in his area of specialization. The thesis is defended in an oral examination, which also covers the subject matter of his advanced work as a whole.

Entrance Requirements for Graduate Study

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions:

Undergraduate preparation for this program should include: mathematics through college algebra and one year of differential calculus; at least one year of an experimental science at the college level; and a course in principles of economics. An undergraduate course in elementary psychology is desirable. In some cases, deficiencies in preparation may be remedied by summer study prior to enrollment or even by special work during the first year of graduate study. The Graduate Committee is willing to consider the particular needs of any applicant who is strongly motivated to study in the School and who has demonstrated high intellectual capacity.

ADMISSION TEST FOR GRADUATE STUDY IN BUSINESS

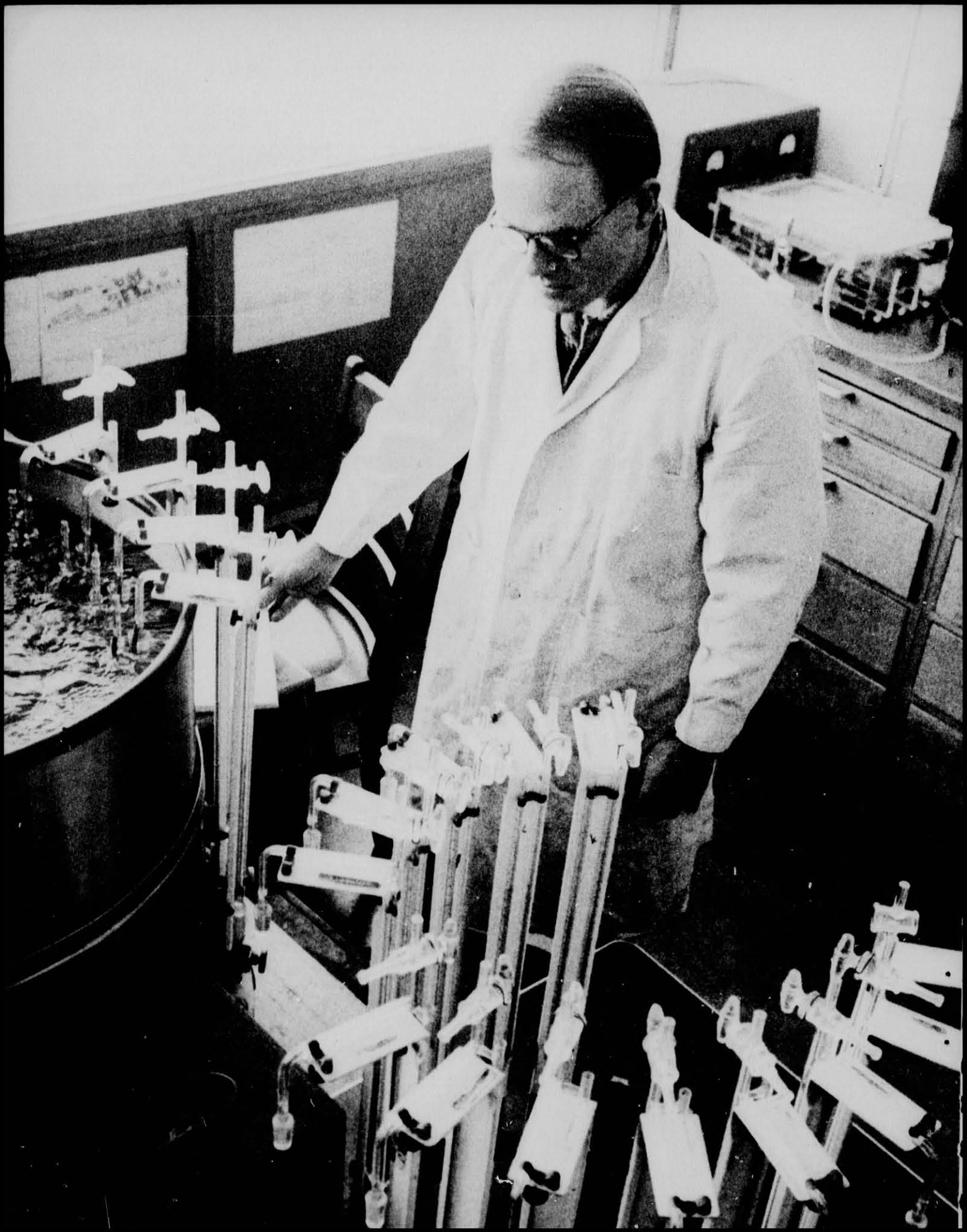
All candidates for admission to graduate study in the School of Industrial Management, other than applicants for the Executive Development Program (see below), are required to take the Admission Test for Graduate Study in Business. This test is administered by the Educational Testing Service, Princeton, New Jersey; information about dates and locations at which the test will be administered may be obtained from that agency.

EXECUTIVE DEVELOPMENT PROGRAMS IN INDUSTRIAL MANAGEMENT

The School of Industrial Management provides two programs for business executives who wish to extend their knowledge of the fundamentals underlying effective management. Applicants for these programs are nominated by their companies.

The *Sloan Fellowships in Executive Development*, available under special grants of the Alfred P. Sloan Foundation, are awarded to exceptionally able young executives about to reach major managerial responsibilities. The Fellowships provide for a twelve-month study of the essentials of business management. A part of this program is taken in conjunction with the regular graduate program and may lead to the degree of Master of Science in Industrial Management.

The *Program for Senior Executives* is an intensive ten-week course of study designed for the mature executive already in or preparing for a position of major managerial responsibility. Enrollment is limited to 24 qualified executives in each of the two ten-week sessions held in the spring and fall each year.



SCHOOL OF SCIENCE 9.

The role of science at M.I.T. is described by the Dean of the School.

GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D., D.ENG.
Dean

SCIENCE COUNCIL

IRWIN WHITING SIZER, PH.D.
Head, Department of Biology
ARTHUR CLAY COPE, PH.D., SC.D.
Head, Department of Chemistry
ROBERT RAKES SHROCK, PH.D.
Head, Department of Geology and Geophysics
WILLIAM TED MARTIN, PH.D.
Head, Department of Mathematics
HENRY GARRETT HOUGHTON, SC.D.
Head, Department of Meteorology
NEVIN STEWART SCRIMSHAW, PH.D., M.D.
Head, Department of Nutrition, Food Science and Technology
WILLIAM WEBER BUECHNER, PH.D., SC.D.
Acting Head, Department of Physics

EXECUTIVE OFFICERS AND DEPUTY HEADS

PATRICK DAVID WALL, M.D.
Department of Biology
LEICESTER FORSYTH HAMILTON, S.B.
Department of Chemistry
PATRICK MASON HURLEY, PH.D.
Department of Geology and Geophysics
RICHARD DONALD SCHAFER, PH.D.
Department of Mathematics
SAMUEL ABRAHAM GOLDBLITH, PH.D.
Department of Nutrition, Food Science and Technology
GEORGE GRAHAM HARVEY, PH.D.
Department of Physics

Science is an effort to see as deeply as possible into the nature of the physical world, to understand the relationships among the phenomena of nature. Today science is one of the most exciting of human activities because of the rapidity with which it is providing new insights and affecting human culture.

The scientist, in carrying on his work, has a great variety of opportunities open to him. He is needed as a teacher at all levels of education. He is encouraged as an individual to seek and pursue new directions for the extension of knowledge. Great projects involving the teamwork of hundreds or even thousands of trained people need scientists at all levels of their organization. The scientist is wanted as an administrator in enterprises involving the work of other scientists and engineers.

The School of Science at M.I.T. offers a broad training which fits students for work in any of these activities. Participation in the research programs being carried out by the staff provides additional training in many highly specialized fields and gives the prospective scientist an insight into the details of how scientific knowledge grows.

The teaching and research activities in the School of Science may be classified, broadly speaking, into four fields —

physical sciences, life sciences, earth sciences, and mathematics — the latter a language common to all science.

The physical sciences are concerned with the structure and interaction of matter and energy. Particularly active in this category at present are studies of atomic nuclei, of elementary particles, and of the great concentrations of energy which can be released in nuclear reactions; of electron physics and the incredibly varied ways in which the motion of this lightest of the particles can be used; the structures of atoms and molecules and of the electric and magnetic interaction of their various parts; the structures of liquids and solids, of metals, of insulators, of semiconductors, and the analysis and building up of molecular assemblages of increasing complexity.

The life sciences cover a very broad field. The most fundamental division is concerned with molecular biology and the chemistry of the molecules found in living cells. These molecules occur in a wide variety of forms, from the simplest inorganic and organic types up to the most complex known, the protein molecules. The properties of these molecules, when gathered together, govern the structure and the energy-converting properties of living systems. In cellular biology the scientist studies the structure, function, and origin of whole cells. In systems biology he examines the combined effects of aggregates of similar cells whose coordinated action determines particular activities of an entire plant or animal. Finally, psychologists, sociologists, and ecologists study the input-output relationships of the whole organism. Teaching and research in all these fields and in the relations between them are carried out at M.I.T. in biology and related departments.

In the earth sciences a great variety of physical and chemical phenomena present themselves in complex systems that call for a penetrating application of the basic concepts of the physical sciences. Much of the field of classical physics, not related to the atom or its nucleus, was historically developed in the study of these earth science problems, and recent advances in our understanding of the earth's atmosphere, of weather prediction and control, and of the seas and oceans are continuations of this effect. The history and development of the earth in its present form, the dynamics of its interior and surface, its magnetic field, its electrical and chemical constitution — these are all studies in geophysics, geology, oceanography, and meteorology.

Mathematics plays an increasingly important role in all of science, and mathematicians are continuing their tradition of fruitful cooperation and progress in both pure and applied mathematical fields.

The School of Science at M.I.T. has close and important relationships with the other schools, with the surrounding community, and with the nation. The continuing close contact of our staff with a wide variety of problems encountered by industry and by state and national governments provides a most stimulating atmosphere for study.

GEORGE R. HARRISON

THE UNDERGRADUATE CURRICULA IN THE SCHOOL OF SCIENCE

The S.B. curricula in the School of Science consist of a common program of general education emphasizing science, mathematics, and the humanities and social sciences (the General Institute Requirements) and groupings of subjects appropriate to specialization in particular fields of science (the Departmental Programs). The General Institute Requirements are given below. The Departmental Programs are given by each department on the following pages.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. Typical Course schedules are issued each term by the Registrar with the Class Schedules. Electives within the Departmental Program may include two additional humanities or social science subjects. R.O.T.C. subjects may be used according to the specifications in Section 2.

				Total units
GENERAL INSTITUTE REQUIREMENTS				
5.01	[1]GENERAL CHEMISTRY	4	2	5
5.02	[1]GENERAL CHEMISTRY	4	2	5
8.01	[1]PHYSICS	4	1	6
8.02	[1]PHYSICS	4	1	6
8.03	PHYSICS			
or		4	1	5
8.031	PHYSICS			
8.04	PHYSICS			
or		4	1	5
8.041	[2]PHYSICS			
18.01	[1]CALCULUS	3	0	6
18.02	[1]CALCULUS	3	0	6
18.03	CALCULUS	3	0	6
18.04	DIFFERENTIAL EQUATIONS	3	0	6
21.01	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.02	[1]INTRODUCTION TO THE HUMANITIES	3	0	5
21.03	MODERN WESTERN IDEAS AND VALUES	3	0	5
21.04	MODERN WESTERN IDEAS AND VALUES	3	0	5
	[1]*Freshman electives*		12	
	[3]*Humanities and social science electives*		32	
				176

A thesis or project of at least 9 units is required in each curriculum in the School of Science, except in Mathematics. Each Departmental Program states the minimum thesis units required in that curriculum.

[1] Subjects of the common first-year program. See pages 38–39.

[2] 8.041, if selected, must be followed by 8.051 (or 8.05).

[3] See pages 39–42 for the humanities and social science program.

Department of Biology

IRWIN WHITING SIZER, PH.D.
Professor of Biochemistry; Head of the Department
PATRICK DAVID WALL, M.D.
Professor of Physiology; Executive Officer
FRANCIS OTTO SCHMITT, PH.D., SC.D.
Institute Professor; Professor of Biology
JOHN MACHLIN BUCHANAN, PH.D.
Professor of Biochemistry; in charge of the Division of Biochemistry
DAVID FLOYD WAUGH, PH.D.
Professor of Biophysics
CYRUS LEVINTHAL, PH.D.
Professor of Biophysics
SALVADOR EDWARD LURIA, M.D.
Professor of Microbiology
BORIS MAGASANIK, PH.D.
Professor of Microbiology
DONALD ARTHUR GLASER, D.SC., PH.D.
Professor of Biophysics (Visiting)
VERNON M. INGRAM, PH.D., D.SC.
Professor of Biochemistry
ALEXANDER RICH, M.D.
Professor of Biophysics
JOHN RADER PLATT, PH.D.
Professor of Communication Sciences (Visiting)
BERNARD SIDNEY GOULD, PH.D.
Associate Professor of Biochemistry
KURT SIEGFRIED LION, DR.ING.
Associate Professor of Applied Biophysics
CECIL EDWIN HALL, PH.D.
Associate Professor of Biophysics
EUGENE BELL, PH.D.
Associate Professor of Biology
JEROME YSRAEL LETTVIN, PH.D.
Associate Professor of Physiology
GENE MONTE BROWN, PH.D.
Associate Professor of Biochemistry
EDWARD HERBERT, PH.D.
Assistant Professor of Biology
PHILLIPS WESLEY ROBBINS, PH.D.
Assistant Professor of Biochemistry
CORRADO BAGLIONI, M.D.
Assistant Professor of Genetics
JAMES EDWIN DARNELL, JR.
Assistant Professor of Biology

Lecturers

IGOR BERT DAWID, PH.D.
LEO CARL MARIA DEMAEYER, PH.D.
HUMBERTO FERNANDEZ-MORAN, M.D., PH.D.
HARUO OZEKI, PH.D.

Instructors

ANTONY OLIVER WARD STRETTON, B.A.
EMANUEL MANN ROTH, M.D.

Research Associates

KLAUS HERMANN ALTGELT, PH.D.
ROBERT FREDERICK BILS, PH.D.
EDWARD HING LOY CHUN, PH.D.
PETER FITZGERALD DAVISON, PH.D.
HOWARD MARVIN DINTZIS, PH.D.
MARIE-LUISE DIRKSEN, PH.D.
PAUL DREIZEN, M.D.
NAOMI COWEN FRANKLIN, PH.D.
DOROTHY KEPPEL FRASER, PH.D.
DAVID MICHAEL FREIFELDER, PH.D.
FRANCIS HUNEEUS-COX, M.D.
ELIZABETH BEACH KELLER, PH.D.
MARTHA LOUISE HOCH, PH.D.
JAMES FREDERICK KOERNER, PH.D.
WALTER LANG KOLTUN, PH.D.
ROBERT LANGRIDGE, PH.D.
DAVID EDGAR LEVENTHAL, PH.D.
ELIZABETH MCFALL, PH.D.
ADELE MAGASANIK, PH.D.
GEORG KARL MANNER, PH.D.
MICHAEL ARTHUR NAUGHTON, PH.D.
DÖRTHE PFAHL
HELEN RUTH REVEL, PH.D.
SPENCER ROSENTHAL, PH.D.
HARRIET EMILIE SCHWENK, M.A.
LAWRENCE STARK, M.D.
T. K. SUNDARAM
KEN-ICHI TOMITA, PH.D.
ANNAMARIA TORRIANI-GORINI, PH.D.
TAKAHIRO UCHIDA, M.D.
A. ULLMAN
BERT LESTER VALLEE, M.D.
JOHN SAMUEL WIBERG, PH.D.

Professors Emeriti

SAMUEL CATE PRESCOTT, SC.D.
Professor of Industrial Biology, Emeritus
CLAIR ELSMERE TURNER, DR.P.H., SC.D.
Professor of Public Health, Emeritus

BIOLOGY

The field of biology has undergone an impressive development during the last twenty-five years. From the conventional fields of classical botany and zoology has evolved a new field of scientific endeavor. Today biology is an exact science, utilizing physics and chemistry and surpassing both these fields in its scope and its immediate importance to man's life and health. New scientific concepts have emerged from this development; the experimental means of the classical biologist are supplemented by modern research methods. The research laboratory of today's biologist comprises electronic and optical systems of all kinds, electron microscopes, and mass spectrographs, as well as many of the methods of electrical and nuclear instrumentation.

This new approach to the biological sciences is especially at home in the M.I.T. environment, where there are important activities and facilities in all the physical sciences. The Department of Biology thus offers unusual opportunities to undergraduate, graduate, and postdoctoral students.

THE UNDERGRADUATE CURRICULUM

Life Sciences (Course VII)

The undergraduate curriculum in the biological sciences is designed to prepare students for teaching and research careers in biology, for graduate study, and for work in industries which are concerned with biological materials and fermentation processes. In addition, the Department places great emphasis on its premedical training program. Aiding in this program are a dozen or more medical doctors who have come to the Department for special postdoctoral studies and research. Students who graduate from the program find that it is an excellent preparation for future study in medical school.

The Course stresses the application of quantitative, analytical methods in the subjects of pure biology; hence particular emphasis is given to those fields which, in the present stage of development, are susceptible of such treatment. Since modern medicine is rapidly becoming less empirical and more scientific, it is especially important that those who wish to prepare for medical research become acquainted with the quantitative approach to biological phenomena.

The student ordinarily takes general biology and organic and analytical chemistry in his second year; genetics and cytology, developmental biology, and physical chemistry in his third year; and biochemistry and physiology in the fourth year. The thesis is also written during the fourth year. Both professional and general electives may be taken during the last two years.

The Course leads to the degree of Bachelor of Science in Life Sciences. The curriculum requirements for the degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 155*)					176
PHYSICS 8.03 and 8.04 are prescribed.					
DEPARTMENTAL PROGRAM					
	Required subjects				
7.01	GENERAL BIOLOGY I	3	0	4	
7.011	GENERAL BIOLOGY LABORATORY I	0	3	0	
7.02	GENERAL BIOLOGY II	3	0	4	
7.021	GENERAL BIOLOGY LABORATORY II	0	3	1	
7.03T	GENETICS AND CYTOLOGY	2	0	4	
7.031	GENETICS AND CYTOLOGY LABORATORY	0	4	0	
7.05	GENERAL BIOCHEMISTRY	3	0	6	
7.051	GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
7.06	GENERAL PHYSIOLOGY	3	0	6	
7.21T	GENERAL MICROBIOLOGY	3	0	6	
5.41	ORGANIC CHEMISTRY I	4	0	4	
5.416	ORGANIC PREPARATIONS I	1	5	0	
5.14	ANALYTICAL CHEMISTRY I	3	0	3	
5.142	ANALYTICAL CHEMISTRY LABORATORY I	1	4	0	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
5.611	PHYSICAL CHEMISTRY LABORATORY I	0	4	2	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
5.621	PHYSICAL CHEMISTRY LABORATORY II	0	4	2	
	THESIS		12		
					131
	Elective subjects				
	Unspecified				53
Total units required for the S.B. degree					360

GRADUATE STUDY IN BIOLOGY

The Department of Biology offers graduate work leading to the degrees of Master of Science in Biology, Biochemistry, or Biophysics, and Doctor of Philosophy in Biology in any one of the following fields of specialization: analytical biology, physiology, microbiology, biochemistry, and biophysics.

The Master's degree is not a prerequisite for a program of study leading to the doctorate. Master's candidates may, by permission, change to a doctoral program without loss of credit.

The Department has exceptional facilities for graduate education, not only in basic analytical biology but also in many specialized fields. Students may prepare for careers in teaching,

in pure and applied biological research, in medical research, and in many fields of industry and industrial research, such as biophysical, biochemical, pharmaceutical, leather, oil, fermentation, and other industries. The educational program is based upon a number of general and specialized subjects and assignments and upon the student's active participation in the Department's research projects or his own research work.

Research facilities are available for a wide variety of fields in analytical biology, biochemistry, biophysics, and microbiology.

ANALYTICAL BIOLOGY

The laboratories of biology apply chemical and physical methods to modern problems of biology. Major areas of research include molecular biology; analytical cytology; physiological genetics; cellular, sensory, and neuro-physiology; and growth and differentiation. Specific current research projects include the chemistry and structure of nerve tissue, connective tissue and chromosomes, electrical properties of nerve and muscle, and the study of tissues in culture.

BIOCHEMISTRY

The laboratories of the Division of Biochemistry are equipped with the most modern tools for teaching and research. Special equipment for the isolation and characterization of enzymes, a radioactivity center, and a mass spectrograph are some of the devices in current use in these laboratories for the solution of problems in enzymology, biosynthesis of proteins, nucleic acids and co-enzymes, intermediary metabolism, and microbiology.

BIOPHYSICS

The physical aspects of biological problems are approached in the biophysical laboratories through the use of techniques such as X-ray diffractions, electron microscopy, ultracentrifugation, electrophoresis, and spectroscopy, as well as through the development of new instruments. Current research problems lie in the area of the structures of proteins, polysaccharides, and nucleic acids; the physical chemistry of proteins and their interactions; communications biophysics; and instrumentation for use in biology and medicine.

Attention is directed to the cooperative arrangement with Harvard University described in Section 3 of this Catalogue.

MICROBIOLOGY

The general properties of microorganisms are stressed, with special emphasis on microbial genetics and intermediary metabolism. Bacterial and mammalian viruses are considered, with special emphasis on problems of reproduction. Microorganisms are compared with mammalian cells in tissue culture.

Entrance Requirements for Graduate Study

The Department modifies the general Institute requirements for graduate study (see Section 3) as follows:

Mathematics. CALCULUS (18.01, 18.02).
Physics. One year of college physics.
Chemistry. ORGANIC CHEMISTRY I (5.41).
Professional Subjects. GENERAL BIOCHEMISTRY AND PHYSIOLOGY OR MICROBIOLOGY.

Deficiencies in the subjects listed above may be removed, if not too extensive, while pursuing a graduate program.

Requirements for Advanced Degrees

There are no specified programs for degree work, since the subjects required vary with the field of specialization. Each student selects his own program, according to certain broad principles, after consultation with the Graduate Committee of the Department.

In addition to the general requirements for advanced degrees (see Section 3), the Department requires all students to take BIOLOGY SEMINAR (7.31, 7.32). A reading knowledge of French and German is required for a Doctor's degree.

Assistantships and Fellowships

A number of qualified students are appointed each year as teaching or research assistants. A research assistant may be permitted to use the results of his assigned research work in a graduate thesis, with possible acceleration of his program. In addition, a number of predoctoral and postdoctoral fellowships are available in analytical biology, physiology, biochemistry, and biophysics. Information about assistantships and fellowships is available from the Head of the Department; applications for the fall term must be made before the March 31 preceding.

Department of Chemistry

ARTHUR CLAY COPE, PH.D., SC.D.
Professor of Organic Chemistry; Head of the Department
LEICESTER FORSYTH HAMILTON, S.B.
Professor of Analytical Chemistry, Emeritus; Lecturer; Executive Officer
WALTER CECIL SCHUMB, PH.D.
Professor of Inorganic Chemistry, Emeritus; Lecturer
GEORGE SCATCHARD, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus; Lecturer
JAMES ALEXANDER BEATTIE, PH.D.
Professor of Physical Chemistry, Emeritus; Lecturer
CHARLES DUBOIS CORYELL, PH.D.
Professor of Chemistry
ISADORE AMDUR, PH.D.
Professor of Physical Chemistry
JOHN CLARK SHEEHAN, PH.D.
Professor of Organic Chemistry
WALTER HUGO STOCKMAYER, PH.D. (*Absent*)
Professor of Physical Chemistry
RICHARD COLLINS LORD, PH.D., SC.D.
Professor of Chemistry; Director of the Spectroscopy Laboratory
GEORGE ELBERT KIMBALL, PH.D.
Professor of Chemistry (Visiting)
CLARK CONKLING STEPHENSON, PH.D.
Professor of Chemistry
GEORGE HERMANN BÜCHI, D.SC. (*Absent*)
Professor of Chemistry
JOHN WITHERS IRVINE, JR., PH.D., SC.D.
Professor of Chemistry
CHARLES GARDNER SWAIN, PH.D.
Professor of Chemistry
DAVID NEWTON HUME, PH.D.
Professor of Chemistry
DAVID POWELL SHOEMAKER, PH.D.
Professor of Chemistry
FRANK ALBERT COTTON, PH.D.
Professor of Chemistry
LOUIS HARRIS, PH.D.
Associate Professor of Physical Chemistry
AVERY ALLEN ASHDOWN, PH.D.
Associate Professor of Organic Chemistry, Emeritus; Lecturer; Secretary of the Society of Arts
STEPHEN GERSHOM SIMPSON, PH.D.
Associate Professor of Analytical Chemistry, Emeritus; Lecturer
NICHOLAS ATHANASIUS MILAS, PH.D., D.SC.
Associate Professor of Organic Chemistry
EDMUND LEE GAMBLE, PH.D.
Associate Professor of Inorganic Chemistry
LAWRENCE JOSEPH HEIDT, PH.D.
Associate Professor of Physical Chemistry
FREDERICK DAVIS GREENE, II, PH.D.
Associate Professor of Chemistry
JOHN STEWART WAUGH, PH.D.
Associate Professor of Chemistry
CARL WESLEY GARLAND, PH.D.
Associate Professor of Chemistry
HERBERT OTIS HOUSE, PH.D.
Associate Professor of Chemistry
IRWIN OPPENHEIM, PH.D.
Associate Professor of Chemistry
WILLIAM ROBERT MOORE, PH.D.
Assistant Professor of Chemistry
WALTER ROLLIER THORSON, PH.D.
Assistant Professor of Chemistry
KLAUS BIEMANN, PH.D.
Assistant Professor of Chemistry
JAMES WILLIAM ROSS, JR., PH.D.
Assistant Professor of Chemistry
DIETMAR SEYFERTH, PH.D.
Assistant Professor of Chemistry
GLENN ALLEN BERCHTOLD, PH.D.
Assistant Professor of Chemistry
GLEN EVERETT GORDON, PH.D.
Assistant Professor of Chemistry
GORDON G. HAMMES, PH.D.
Assistant Professor of Chemistry

Research Associate

STEPHEN MEARS NAGY, SC.D.

Professors Emeriti

FREDERICK GEORGE KEYES, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus
MILES STANDISH SHERRILL, PH.D.
Professor of Physical Chemistry, Emeritus
EARLE BOWMAN MILLARD, PH.D.
Professor of Physical Chemistry, Emeritus
WALTER CECIL SCHUMB, PH.D.
Professor of Inorganic Chemistry, Emeritus; Lecturer
LEICESTER FORSYTH HAMILTON, S.B.
Professor of Analytical Chemistry, Emeritus; Lecturer
GEORGE SCATCHARD, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus; Lecturer
JAMES ALEXANDER BEATTIE, PH.D.
Professor of Physical Chemistry, Emeritus; Lecturer
AVERY ADRIAN MORTON, PH.D.
Professor of Organic Chemistry, Emeritus
ALPHEUS GRANT WOODMAN, S.B.
Associate Professor of Analytical Chemistry, Emeritus
AVERY ALLEN ASHDOWN, PH.D.
Associate Professor of Organic Chemistry, Emeritus; Lecturer
STEPHEN GERSHOM SIMPSON, PH.D.
Associate Professor of Analytical Chemistry, Emeritus; Lecturer
RALPH CHILLINGWORTH YOUNG, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus
CHARLES MONTGOMERY WAREHAM, S.B.
Associate Professor of Inorganic Chemistry, Emeritus

CHEMISTRY

The Department of Chemistry offers a single undergraduate Course, sufficiently flexible in its electives so that it provides excellent preparation for careers in many different areas of chemistry, and graduate programs for three advanced degrees. There are excellent opportunities for study and research in physical, organic, inorganic, nuclear, and analytical chemistry. In addition, the Department is responsible for undergraduate and graduate instruction in chemistry for students in many other Institute Courses.

THE UNDERGRADUATE CURRICULUM

Chemistry (Course V)

The main objective of the Course in Chemistry is to provide a general education based on science, both for those who seek the Bachelor's degree and a career in some field in which a sound knowledge of chemistry is important and for those who wish to go on to graduate study and a professional career in chemistry. Students receive thorough instruction in the principles of inorganic, organic, analytical, and physical chemistry, supplemented by instruction in mathematics and physics and in the humanities and languages, including English, history, German, French, and other nonprofessional subjects.

Elective time allows each student to extend his knowledge in fields of special interest. Students intending to take graduate work, for example, may elect subjects which will increase their ability to utilize the opportunities in graduate study. Students intending to enter industry may take subjects which offer the fundamentals in a selected field of science or engineering. Elective time may also be used for additional subjects in the humanities.

The Course aims to stimulate and develop the research attitude, and the curriculum includes a thesis in the fourth year, to give the student an opportunity to demonstrate his aptitude for creative effort.

The Course is a carefully planned sequence of required subjects with an opportunity for a choice of restricted electives in three fields of advanced chemistry, additional free elective time, and a liberal policy of substitution. The Course leads to the degree of Bachelor of Science in Chemistry. The curriculum requirements for the degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 155*)					**176**
PHYSICS 8.03 and 8.04 are prescribed.					
DEPARTMENTAL PROGRAM					
	Required subjects				
5.41	ORGANIC CHEMISTRY I	4	0	4	
5.412	ORGANIC PREPARATIONS I	1	4	0	
5.42	ORGANIC CHEMISTRY II	4	0	4	
5.422	ORGANIC PREPARATIONS II	1	4	2	
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	2	0	4	
5.428	QUALITATIVE ORGANIC ANALYSIS	2	7	1	
5.61	PHYSICAL CHEMISTRY I	4	0	4	
5.613	PHYSICAL CHEMISTRY LABORATORY I	0	6	3	
5.14	ANALYTICAL CHEMISTRY I	3	0	3	
5.141	ANALYTICAL CHEMISTRY LABORATORY I	1	8	0	
5.62	PHYSICAL CHEMISTRY II	4	0	4	
5.623	PHYSICAL CHEMISTRY LABORATORY II	0	6	3	
5.16	ANALYTICAL CHEMISTRY II	3	0	3	
5.161	ANALYTICAL CHEMISTRY LABORATORY II	1	4	2	
	[1]LANGUAGE	3	0	5	
	THESIS		30		
					144
	Elective subjects				
	Specified				
	Inorganic chemistry — at least 6 units from:				
5.04	PRINCIPLES OF INORGANIC CHEMISTRY II	2	0	4	
5.09	RADIOCHEMISTRY *and*	3	0	3	
5.091	RADIOCHEMISTRY LABORATORY	0	3	2	
	Organic chemistry — at least 6 units from:				
5.43	ORGANIC CHEMISTRY III	2	0	4	
5.44	ORGANIC CHEMISTRY IV	2	0	4	
5.51	ADVANCED ORGANIC CHEMISTRY: SYNTHESIS	2	0	4	
5.54	PHYSICAL ORGANIC CHEMISTRY	2	0	4	
5.55	ORGANIC CHEMISTRY: NATURAL PRODUCTS	2	0	4	
	Physical chemistry — at least 6 units from:				
5.67	INTRODUCTION TO ATOMIC AND MOLECULAR STRUCTURE	2	0	4	
5.68	KINETICS OF CHEMICAL REACTIONS	2	0	4	
5.70	INTRODUCTION TO STATISTICAL THERMODYNAMICS	2	0	4	
5.71	CHEMICAL THERMODYNAMICS I	2	0	4	
5.75	INTRODUCTORY WAVE MECHANICS	2	0	4	
					18
	Unspecified				**22**
Total units required for the S.B. degree					**360**

[1] The language should be ELEMENTARY GERMAN (23.11 or 23.12) or INTERMEDIATE GERMAN (23.13 or 23.14T). French may be substituted by those having a reading knowledge of German. All students should acquire a reading knowledge of German and French, and additional subjects in these languages will be credited as elective.

GRADUATE STUDY IN CHEMISTRY

Graduate chemists have a wide choice of careers. They are needed to serve as investigators and to teach and direct investigational work in

academic institutions, in industry, in endowed research institutions, and in government bureaus. Industries in particular have come to realize the desirability and even necessity of supporting fundamental scientific investigations relative to their processes, as a basis for their future development.

The Department of Chemistry offers graduate programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Chemistry. Details of these programs, which differ according to whether the candidate chooses to specialize in analytical, inorganic and nuclear, organic, or physical chemistry, are recorded below. Students working toward the doctorate are expected to choose one of these four fields of specialization; students working toward the Master's degree may make a similar selection or may take a program which includes an approved combination of these fields.

Attainment of the Master's degree is not prerequisite to a program of study leading to a doctorate. Master's candidates may, by permission, change to the corresponding doctoral program without loss of credit.

PHYSICAL CHEMISTRY

Graduate subjects in physical chemistry cover the fundamentals of thermodynamics, statistical mechanics, kinetic theory, and molecular structure. The Minor in mathematics and physics broadens this basis. The research gives intensive specialization in a narrower field and develops experimental technique and ability to carry on independent investigations.

Research in physical chemistry is being carried out in the following fields, and the laboratory is especially well, often uniquely, equipped for such research:

Pressure-volume-temperature relations of gases and liquids.
Heat capacities and latent heats at low temperatures.
Properties of gases at low pressures.
Diffusion of gases.
Scattering and other properties of molecular beams.
Electromotive force in concentration cells, and oxidation-reduction potentials.
Vapor pressures of liquid solutions.
Infra-red, ultra-violet and Raman spectroscopy.
Precision photometry.
Kinetics of thermal and photochemical reactions.
Kinetics of fast reactions.
Kinetics of enzymatic reactions.
Spectrophotometric studies of metallic ions and organic compounds in visible and ultraviolet light.
Properties of high polymers.
Properties of protein solutions.
Properties of ion exchangers.
Optical and electrical properties of thin metal deposits.
Study of crystal structure by X-ray and neutron diffraction.
Nuclear resonance studies of the constitution of molecules and crystals.
Lattice dynamics and low-temperature elastic constants.
Absorption spectra of adsorbed molecules.
Theoretical electronic structure of molecules.
The Mössbauer effect.

ORGANIC CHEMISTRY

Subjects offered in the graduate program aim to develop a sound knowledge of fundamentals and a familiarity with current progress in the most active and important branches of organic chemistry. Each student undertakes a research problem which forms the nucleus of his graduate work, and, through the experience of conducting an experimental investigation leading to the Doctor's or Master's thesis, learns the research attitude and method of approach and acquires training in the specialized techniques of organic research. Basic graduate subjects in organic chemistry give a broad coverage of organic reactions and their application to synthetic and structural problems and theoretical organic chemistry.

The principal areas of research in organic chemistry under study in the Department include investigations of natural products and physiologically active compounds (structure determination and synthesis of alkaloids, terpenes, steroids, antibiotics, peptides and vitamins); elucidation of the mechanisms of reactions and the relation of structure to reactivity; investigations directed toward the discovery and application of new synthetic methods; and investigations of organometallic compounds, peroxides, and photochemical transformations.

INORGANIC AND NUCLEAR CHEMISTRY

Inorganic Chemistry

Opportunities for research in inorganic chemistry, nuclear chemistry, and allied fields of interest have never been more abundant than they are today. In recent years, remarkable advances have been reported in many areas, including the utilization of the less familiar elements such as titanium, niobium, tantalum, the rare earth metals, uranium, and the synthetic heavier elements; the isolation of small quantities of the compounds of other hitherto unknown elements such as technetium (element No. 43) and promethium (element No. 61); and the utilization of certain nonmetallic elements, such as selenium and fluorine.

Inorganic chemistry has two aspects, the preparative and the physicochemical, which are by no means separate in practice.

In addition to the impetus which has resulted from the increased accessibility to study of new areas of the periodic table, the theoretical or physico-chemical side of inorganic chemistry has been offered challenging new means of attack on basic problems by recent developments of techniques and advances in theory. Infrared and Raman spectroscopy, visible and ultraviolet spectrometry, magnetic studies of various types including nuclear and electron resonance, as well as new methods for dealing with such problems as the kinetics of the many very fast inorganic reactions are becoming a part of the inorganic chemist's body of essential techniques.

The contributions of the laboratory, therefore, will be found to include the isolation and study of numerous inorganic compounds, and physical-chemical investigations of the structures, bonding, and reactivities of inorganic compounds. Particular attention is being given to the chemistry of organometallic compounds, to the elaboration of the chemistry of some of the nontransition elements and to physical-chemical and preparative studies of the complexes of transition metals. The initiative of the student in suggesting problems in other areas is encouraged.

Nuclear Chemistry

The Institute's Laboratory for Nuclear Science provides access to outstanding facilities for research in nuclear chemistry; a large cyclotron, synchrotron, linear accelerator, and Van de Graaff accelerator are available for the study of nuclear reactions and the preparation of radionuclides. The M.I.T. reactor also offers excellent opportunities for activation with neutrons, for study of the properties of radionuclides and of effects of radiation on matter.

The research worker may undertake detailed studies of nuclear reactions in the low- or high-energy regions, including fission and spallation; or studies of nuclear properties as a function of nuclear structure, including search for and identification of new species. The radiochemical resources are favorable for a variety of studies of chemical properties by tracer methods, including the properties of elements at very low concentration and the factors to be controlled in the development of new separation methods for constituents of radioactive mixtures. Other studies involve the physical-inorganic principles underlying the chemical problems of nuclear science and the applications of radiotracer techniques to general chemical problems. Modern counting equipment is available in the Department.

ANALYTICAL CHEMISTRY

The graduate curriculum in analytical chemistry is designed to prepare men for leadership both in industrial and in academic laboratories. The program provides a broad background in inorganic, physical, and organic chemistry and places emphasis upon both organic and inorganic aspects of analytical chemistry. The subjects stress principles and methods; the thesis aims at providing a varied research experience and specialization in a field of limited scope.

The laboratory is unusually well equipped for studies involving modern instrumental methods. The student is able to employ a wide variety of methods, as well as to use a number of different instruments designed to carry out the same general technique and compare their performances. Research is being carried on in polarography; electrochemical theory; electrodeposition of trace elements; fluorescence; spectrophotometry; flame photometry; ion exchange; gas chromatography; fused salt systems; complex formation; separation chemistry; nonaqueous titrations; thermometric titrations; photometric titrations; the analytical chemistry of fission elements; development of chemical and instrumental methods for the elucidation of the structure of organic compounds and their application to natural products, such as alkaloids and peptides; and mass spectroscopy of organic molecules.

Entrance Requirements for Graduate Study

The general admission requirements are those set forth in Section 3 of this Catalogue, with the following exceptions and additions:

Mathematics. Doctoral candidates with their Major in analytical, inorganic, or organic chemistry need not present 18.04 DIFFERENTIAL EQUATIONS.

Professional Subjects. All candidates for admission to graduate work in this Department must present equivalents of the following subjects:

GENERAL CHEMISTRY (5.01, 5.02)
QUALITATIVE INORGANIC ANALYSIS
QUANTITATIVE ANALYSIS
ORGANIC CHEMISTRY I and II (5.41, 5.42)
ORGANIC PREPARATIONS I (5.412)
ORGANIC PREPARATIONS II (5.422)
QUALITATIVE ORGANIC ANALYSIS (5.428)
PHYSICAL CHEMISTRY I and II (5.61, 5.62)
PHYSICAL CHEMISTRY LABORATORY I and II (5.613, 5.623)

The Graduate Degrees

MASTER OF SCIENCE IN CHEMISTRY

In addition to the general requirements set forth in Section 3, the candidate must demonstrate by examination to the Department of Modern Languages his ability to read in either German, French, or Russian the scientific literature of his major field.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN CHEMISTRY

For the degree of Doctor of Philosophy or Doctor of Science in a field of chemistry, each candidate must fulfill the requirements listed below.

Candidates for the doctorate in any field of chemistry are required to complete a written qualifying examination. This is offered twice each year, in the weeks preceding the opening of the fall and spring terms (September and February). Doctoral candidates admitted for the summer or fall terms will take the examination just before the fall term begins, and those admitted at the beginning of the spring term will take the examination in the week preceding the opening of the spring term.

Successful completion of the examination upon entrance will enable the student, with the advice of his Registration Officer, to select a program of graduate subjects more advanced in character than would be possible otherwise and to make more rapid progress toward the doctoral degree. Students who fail any part of the examination may select a program that includes more elementary subjects in any field where such registration seems advisable; when the examination is next offered, they are required to repeat that part which they previously failed. Qualifying examination grades are not entered on the student's permanent record.

Satisfactory completion of the qualifying examination automatically certifies the candidate in all the undergraduate deficiencies in subjects in chemistry. A passing grade is prerequisite for the subsequent General Examination in the candidate's field of specialization.

In order to complete the language requirement, the student must pass written examinations in German and in scientific French or Russian before taking his General Examination.

To fulfill the Minor requirement, the student must take at least 24 units of subjects outside of his field of specialization. Candidates majoring in physical chemistry are expected to take the Minor in mathematics or physics.

Each candidate pursues a program of graduate subjects which varies according to his Major field but which ordinarily includes selections from the following subjects:

ANALYTICAL CHEMISTRY

5.16, 5.161, 5.192, 5.193, 5.194, 5.196, 5.67, 5.71, and during each year of residence 5.915, 5.916, 5.951, and 5.952.

INORGANIC AND NUCLEAR CHEMISTRY

5.065, 5.067, 5.71, together with at least 14 units in approved subjects, such as X-RAYS AND CRYSTAL PHYSICS, NUCLEAR PHYSICS, RADIOCHEMISTRY, X-RAY METALLOGRAPHY, or CRYSTALLOGRAPHY, and during each year of residence 5.941 and 5.942.

ORGANIC CHEMISTRY

5.43, 5.44, 5.51, 5.54, 5.55, and during each year of residence 5.913 and 5.914.

PHYSICAL CHEMISTRY

5.70, 5.71, 5.75, and any four of the following subjects: 5.72, 5.73, 5.74, 5.76, 5.77, 5.78, 5.79 and 5.81; and during each year of residence 5.931 and 5.932.

After completing the program of Major subjects, the candidate must pass a comprehensive examination, including both written and oral parts, in his Major field.

In the interpretation of these requirements, the Department will consider the candidate's previous academic record and professional experience, together with his particular aims and objectives, and will take a liberal attitude toward substitution of other subjects of equivalent educational and scientific value. Graduate students are urged to select a research supervisor during the first or second academic term of residence and to plan their program of study in consultation with him and with the chairman of the Department's graduate committee.

Inquiries should be addressed to the Chairman of the Department Committee on Graduate Students.

Teaching Assistants

The Department appoints a number of teaching assistants who are candidates for the degree of Doctor of Philosophy in Chemistry. Teaching assistants serve in the laboratories of the Department and may be asked to conduct recitation sections on a regular part-time schedule throughout the academic year. Inquiries about appointments should be addressed to the Head of the Department.

Department of Geology and Geophysics

ROBERT RAKES SHROCK, PH.D.
Professor of Geology; Head of the Department

PATRICK MASON HURLEY, PH.D.
Professor of Geology; Executive Officer; Chairman of the Faculty

MARTIN JULIAN BUERGER, PH.D.
Institute Professor; Professor of Mineralogy and Crystallography; Director of the School for Advanced Study

FRANCIS BITTER, PH.D.
Professor of Geophysics

HAROLD WILLIAMS FAIRBAIRN, PH.D.
Professor of Geology

COLUMBUS O'DONNELL ISELIN, D.SC.
Professor of Oceanography

WILLIAM STELLING VON ARX, SC.D.
Professor of Oceanography

RAYMOND HIDE, PH.D.
Professor of Geophysics

ROLAND DANE PARKS, E.M., M.S. (*Absent*)
Associate Professor of Mineral Industry

WALTER LUCIUS WHITEHEAD, PH.D.
Associate Professor of Geology, Emeritus; Lecturer

ELY MENCHER, PH.D.
Associate Professor of Geology

WILLIAM HENRY DENNEN, PH.D.
Associate Professor of Geology

JOHN BRACKETT HERSEY, PH.D.
Associate Professor of Oceanography

DAYTON ERNEST CARRITT, PH.D.
Associate Professor of Chemical Oceanography

WILLIAM HAMET PINSON, JR., PH.D.
Associate Professor of Geology

STEPHEN MILTON SIMPSON, JR., PH.D.
Assistant Professor of Geophysics

WILLIAM FRANCIS BRACE, PH.D. (*Absent*)
Assistant Professor of Geology

JOHN WIDMER WINCHESTER, PH.D.
Assistant Professor of Geochemistry

HARRY HUGHES, PH.D.
Assistant Professor of Geophysics

THEODORE RICHARD MADDEN, S.B.
Assistant Professor of Geophysics

THOMAS CANTWELL, PH.D.
Assistant Professor of Geophysics

Lecturers

JOSEPH LINCOLN GILLSON, SC.D.

NORMAN ABRAHAM HASKELL, PH.D.

DONALD JONATHAN MACNEIL, PH.D.

HENRY ADAMS MORSS, JR., PH.D. *Earth Sciences*

Instructors

GEORGE HALSEY BEALL, M.SC.

DAVID GREENEWALT, PH.D.

Professors Emeriti

HERVEY WOODBURN SHIMER, PH.D., SC.D.
Professor of Paleontology, Emeritus

FREDERICK KUHNE MORRIS, PH.D.
Professor of Geology, Emeritus

WALTER LUCIUS WHITEHEAD, PH.D.
Associate Professor of Geology, Emeritus; Lecturer

GEOLOGY AND GEOPHYSICS

The origin, age, and composition of the earth, the physical state of the earth's interior, and the origin of the oceans and atmosphere are among the most challenging and perplexing problems of science. They all lie within the domain of the earth scientists — geologists, geochemists, geophysicists, meteorologists, and oceanographers — but they can be successfully attacked only by using the latest contributions from the physical and engineering sciences.

Our expanding industrial economy is making heavy demands on the petroleum and mineral industries and on the companies that find and develop the raw materials for these industries. Reserves of petroleum and natural gas, of metallic ores, and of many nonmetallic substances such as domestic water are increasingly difficult to maintain. Most of the easy discoveries have been made, the low-cost deposits have been exhausted, and industries must rely in the future on improvements and new developments in geological, geochemical, and geophysical methods in their exploration programs. Industry's needs for men trained in these fields of earth science are shared by research, government, military, and atomic energy organizations engaged in a wide variety of projects related to raw materials, defense, global strategy, and pure scientific discovery.

Thus, careers in geology, geochemistry, geophysics, and oceanography offer a wide variety of work in teaching and research, in governmental bureaus and private and industrial laboratories, in field work in many different parts of the world, and in independent consulting.

Students especially interested in minerals and rocks; in the mineral industries; or in outdoor work in geology or oceanography can arrange excellent programs of study by consulting the appropriate Faculty Counselor.

THE UNDERGRADUATE CURRICULA

Geology and Geophysics (Course XII)

The undergraduate program in Course XII provides students with an opportunity to acquire competence in some aspect of the earth sciences — geology, geophysics, geochemistry, oceanography, or meteorology. The offerings are of sufficient depth and breadth so that a graduate may begin a career in his chosen field or continue with graduate studies. The program is built around a small core of prescribed professional subjects, a large amount of work in prescribed fields within which free selection of individual subjects may be made, and a generous allocation of free electives. A student is thus able to progress toward his own goals at his own pace.

The curriculum for the first year is described on pages 38–39.

In the second year it is expected that students will take MINERALOGY I (12.011), PHYSICAL GEOLOGY (12.301), and HISTORICAL GEOLOGY (12.302) in order to obtain a fundamental understanding of geological processes and materials. Omission of any of these subjects from a student's second-year curriculum will necessitate added effort in his later program. About 10 units of elective time are available in the second term of the second year for students following the usual program of prescribed Institute and departmental subjects. This time may be used to take advantage of offerings in professional subjects; in the prescribed elective subjects in mathematics, physics, chemistry, or electrical engineering; or in the humanities.

In the third year it is expected that students will lay the groundwork for their areas of later concentration. The subjects taken should have broad applicability in the earth sciences in order to assure flexibility of future choice. The different goals of students in the earth sciences and the wide range of subject matter available make it most important that each student carefully consider his program with his Faculty Counselor.

Fourth-year students will, in general, be pursuing subject sequences which simultaneously enhance their professional knowledge, add to their store of fundamental understanding, and increase their appreciation for non-professional matters. The Bachelor's thesis, usually written in the second term but often based on field work done during the previous summer, is an opportunity for the student to take up the challenge of exploring in a professional manner some problem in the earth sciences. Every attempt is made to provide the student freedom of choice of his thesis problem and to provide appropriate time, environment, and supervision for its completion.

In choosing an undergraduate curriculum in Geology and Geophysics, each student should keep in mind the following essential pattern when arranging his program with his adviser:

1. Professional earth science subjects should be taken in an orderly sequence which goes from

subjects of broad applicability to those covering small topics in considerable depth.

2. Subjects in mathematics, physics, chemistry, or electrical engineering should be taken in an orderly sequence and so selected as to support the particular earth science program being followed.

The Course leads to the Degree of Bachelor of Science in Earth Sciences. The curriculum requirements for this degree are presented below.

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 155*)		176
PHYSICS 8.03 and 8.04 are taken except when plans for further study clearly indicate the need for the subject matter of PHYSICS 8.031 and 8.041[1].		
DEPARTMENTAL PROGRAM		
Required subjects		
THESIS		15
Elective subjects		
Specified		
Basic science and engineering subjects more advanced than the General Institute Requirements (mathematics, physics, chemistry, electrical engineering, chemical engineering, etc.) (4 or 5 subjects depending on units)	40 to 45	
Earth science subjects: a combination of subjects selected from at least two of the following categories: geosciences (geology and/or geochemistry, and/or geophysics, meteorology, and oceanography)	30	
Professional electives (9 or 8 subjects)	72 to 67	
Unspecified	32	
		174
Total units required for the S.B. degree		[2]365

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

[2] To this total must be added appropriate field experience, generally obtained in the summer.

Geology and Geophysics (Five-Year Course) (Course XII-A)

The problems that geologists, geochemists, geophysicists, and other earth scientists now have to consider require more basic science and more geological training than ever before, and this situation will certainly be intensified in the future. For this reason, students no longer receive training adequate for certain kinds of professional careers in the earth sciences in the normal four-year program. The primary educational objective of Course XII-A is to train geologists, geochemists, and geophysicists for the future; the five-year plan has been organized with this purpose in view. This plan gives the qualified student maximum opportunity for a broad and thorough training in the basic sciences and a comprehensive training in the different fields of earth science — geology, geochemistry, geophysics, and others. Upon completion of the program he should be able to work in widely diversified fields and on many different kinds of problems in the areas mentioned in the description of the four-year curriculum.

Inasmuch as all requirements, except number of hours of thesis and of unrestricted electives, are the same for both Course XII and Course XII-A, candidates for the five-year plan will generally apply for it by the end of the first term of the senior year; at that time their qualifications will be examined and their preparation for graduate work determined. Since Course XII-A leads to the Master's degree, acceptance of a student for the graduate year will depend partly on his scholastic record and partly on the professional promise he has demonstrated in the field, the laboratory, or professional summer work with some organization.

Course XII-A leads to the degrees of Bachelor of Science in Earth Sciences and Master of Science in Geology and Geophysics, awarded simultaneously at the end of the graduate year.

THE CURRICULUM IN GEOLOGY AND GEOPHYSICS (FIVE-YEAR COURSE) (COURSE XII-A)

The undergraduate curriculum requirements are the same as for Course XII, except that the 15 units of undergraduate thesis are allotted to additional professional subjects.

The graduate requirement is 66 units of graduate study and 30 units of THESIS, a total of 96 units. (Up to 10 units of additional THESIS may be included in the 66 units of graduate study.)

GRADUATE STUDY

Geology and Geophysics

The Department of Geology and Geophysics offers a wide choice of graduate study and research for specialization in the following fields: geochemistry; geophysics; mineralogy; mineral industry; mineral deposits; mineral fuels; petroleum geology; petrology; sedimentation, stratigraphy, and paleontology; structural geology; and theoretical geology. In the borderland between geology, geophysics, geochemistry, and another science, the student may arrange a program of study and research under super-

vision of a special interdepartmental committee. Advanced work in the fields mentioned leads to one of the following degrees: Master of Science in Geology and Geophysics, or Doctor of Philosophy or Doctor of Science in the field of specialization.

The Department offers graduate students an unusual opportunity to pursue study and research in both theoretical and applied geology, X-ray crystallography, geochemistry, and geophysics. Modern laboratory facilities, research instruments, and extensive collections of specimens and materials are available to qualified graduate students. Field studies are included as an essential part of the graduate curriculum in geology, geophysics, and geochemistry, and special arrangements may be made for summer employment and field research with industrial organizations and government agencies.

Oceanography

In cooperation with the Department of Meteorology and the Woods Hole Oceanographic Institution, a program in oceanography is now being offered. The oceans, the atmosphere, and the solid earth are so intimately related that they must often be studied together as parts of a single system. Certain subjects of instruction in geology and in meteorology are directly applicable to oceanographic problems. Five staff members of the Woods Hole Oceanographic Institution now hold part-time faculty appointments at M.I.T. in the two cooperating departments. These oceanographers offer formal lecture subjects and are also available by appropriate arrangement for individual consultation and for thesis advising. Arrangements may also be made for properly qualified M.I.T. graduate students to use the excellent facilities for oceanogaphic research at Woods Hole.

The program in oceanography is under the direct guidance of an interdepartmental committee representing both the Departments of Geology and Geophysics and of Meteorology; it leads to the degree of Master of Science or Doctor of Philosophy in Oceanography.

Entrance Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue.

In addition, the Department requires preparation essentially equivalent to the program of subjects leading to the degree of Bachelor of Science in Earth Sciences at the Institute. If the student is not fully prepared in certain of the required subjects, he usually will be asked to extend his preparation in these while he pursues his advanced work. The subjects to be taken for this purpose will be designated by the Department Committee on Graduate Students after the student's preparation and proposed program of study have been considered. The actual program of advanced subjects and research leading to a graduate degree is arranged by the student and his faculty advisers, to whom he is assigned at the time he first registers and who will generally direct the major part of his program.

The Graduate Degrees

MASTER OF SCIENCE IN GEOLOGY AND GEOPHYSICS OR MASTER OF SCIENCE IN OCEANOGRAPHY

In addition to the general and departmental requirements stated in the preceding paragraphs, the candidate for the degree of Master of Science in Geology and Geophysics or in Oceanography is required to pursue a program of advanced study and research in an area approved by his faculty advisers. Possible fields of specialization are specified above.

THE DOCTORATES

The general requirements for the degrees of Doctor of Philosophy or Doctor of Science are given in Section 3. Possible fields of specialization are indicated above. Departmental requirements for graduate work leading to these degrees are given in the following paragraphs.

The preparation and research ability of any candidate for the doctorate must be such as to satisfy the Department Committee on Graduate Students that he is qualified to undertake advanced study and research. The thesis is expected to be a publishable contribution in the field of the candidate's specialization.

Soon after the student registers in the Department as a doctoral candidate, he will be required to take a qualifying examination, which may be partly oral and partly written; this examination is intended to survey his training and attainments and to serve as a basis for certifying him for a Doctor's program.

The program of graduate work may, with the approval of the Department Committee on Graduate Students, include subjects in other departments for which the student has adequate preparation. Candidates for the doctorate in oceanography will work under the guidance of an interdepartmental committee.

Each candidate for the doctorate must demonstrate that he can read scientific literature in his field of specialization in English and in two other languages; French, German, and Russian are among the appropriate languages. Ordinarily this requirement should be satisfied by the time the General Examination is taken and before undertaking thesis research.

The Minor requirement is generally satisfied by taking at least 24 units of approved study in another department.

Teaching and Research Assistants

The Department regularly appoints 15 to 20 assistants who are candidates for a graduate degree. Teaching assistants conduct regularly scheduled laboratory sections and examinations, grade papers, and prepare teaching materials. Research assistants do assigned work on one of the Department's projects and may be able to use some of the work done toward a thesis. Information about these appointments may be obtained by writing to the Head of the Department.

Department of Mathematics

WILLIAM TED MARTIN, PH.D.
Professor of Mathematics; Head of the Department

RICHARD DONALD SCHAFER, PH.D.
Professor of Mathematics;
Deputy Head of the Department

NORBERT WIENER, PH.D., SC.D.
Institute Professor, Emeritus;
Professor of Mathematics, Emeritus

PHILIP FRANKLIN, PH.D.
Professor of Mathematics;
Secretary of the Faculty

RAYMOND DONALD DOUGLASS, PH.D., SC.D.
Professor of Mathematics, Emeritus; Lecturer

NORMAN LEVINSON, SC.D.
Professor of Mathematics

ERIC REISSNER, DR. ING., PH.D.
Professor of Mathematics

CHIA-CHIAO LIN, PH.D.
Professor of Mathematics

CLAUDE ELWOOD SHANNON, PH.D.
Donner Professor of Science

WARREN AMBROSE, PH.D.
Professor of Mathematics

GEORGE WILLIAM WHITEHEAD, PH.D.
Professor of Mathematics

KENKICHI IWASAWA, DR.SCI.
Professor of Mathematics

ISADORE MANUAL SINGER, PH.D. (*Absent*)
Professor of Mathematics

GERALD BERESFORD WHITHAM, PH.D. (*Absent*)
Professor of Mathematics

IRVING EZRA SEGAL, PH.D.
Professor of Mathematics

GEORGE BRINTON THOMAS, JR., PH.D.
Professor of Mathematics

REIMAR HEINZ LUST, PH.D.
Professor of Mathematics (Visiting)

BERTRAM KOSTANT, PH.D.
Professor of Mathematics (Visiting)

PRESCOTT DURAND CROUT, PH.D.
Associate Professor of Mathematics

GEORGE PROCTOR WADSWORTH, PH.D.
Associate Professor of Mathematics

SAMUEL DEMITRY ZELDIN, PH.D.
Associate Professor of Mathematics, Emeritus; Lecturer
FRANCIS BEGNAUD HILDEBRAND, PH.D.
Associate Professor of Mathematics
NESMITH CORNETT ANKENY, PH.D.
Associate Professor of Mathematics
LOUIS NORBERG HOWARD, PH.D. (*Absent*)
Associate Professor of Mathematics
HARTLEY ROGERS, JR., PH.D.
Associate Professor of Mathematics
HARVEY PHILIP GREENSPAN, PH.D.
Associate Professor of Mathematics
HENRY PRATT McKEAN, JR., PH.D.
Associate Professor of Mathematics
DANIEL BURRILL RAY, PH.D.
Associate Professor of Mathematics
SIGURDUR HELGASON, PH.D.
Associate Professor of Mathematics
DANIEL MARINUS KAN, PH.D.
Associate Professor of Mathematics
ARTHUR PAUL MATTUCK, PH.D.
Associate Professor of Mathematics
MARVIN LEE MINSKY, PH.D.
Associate Professor of Mathematics
FRANKLIN PAUL PETERSON, PH.D.
Associate Professor of Mathematics
FELIX EARL BROWDER, PH.D.
Associate Professor of Mathematics (Visiting)
EKKEHART KRÖNER, PH.D.
Associate Professor of Mathematics (Visiting)
KENNETH MYRON HOFFMAN, PH.D. (*Absent*)
Assistant Professor of Mathematics
GIAN-CARLO ROTA, PH.D.
Assistant Professor of Mathematics
DAVID JOHN BENNEY, PH.D.
Assistant Professor of Mathematics
JAMES GILBERT GLIMM, PH.D.
Assistant Professor of Mathematics
JAMES RAYMOND MUNKRES, PH.D.
Assistant Professor of Mathematics
HUBERTUS JOSEF WEINITSCHKE, PH.D.
Assistant Professor of Mathematics (Visiting)

Lecturers

OMA VEIKKO HAMARA, PH.D.
CHRISTOPHER HUNTER, PH.D.

C. L. E. Moore Instructors

ALLAN HAYES, PH.D.
JAMES DILLON STASHEFF, PH.D.
ALAR TOOMRE, PH.D.
ALBERT EMERSON HURD, PH.D.
NORMAN RONALD LEBOVITZ, PH.D.
JAMES HARRIS SIMONS, PH.D.

Instructors

ROBERT EDWARD BRINEY, PH.D.
RICHARD MORGAN MORONEY, JR., PH.D.
GERALD RALPH STOODLEY, S.B.
RICHARD BRIAN DARST, PH.D.
RAMESH ANAND GANGOLLI, PH.D.
SUFIAN YUNIS HUSSEINI, PH.D.
RONALD JACOBOWITZ, PH.D.
JONATHAN IAN RICHARDS, PH.D.
WILLIAM ERNEST RITTER, A.B.
FRED SCOTT VAN VLECK, PH.D.
FRANCIS PATTON BRETHERTON, PH.D.
THOMAS JOSEPH EISLER, PH.D.
ROSS LEE FINNEY, III, PH.D.
JEROME PAUL LEVINE, PH.D.
GEORGE JOHN MALTESE, PH.D.
MARK MACDONALD ROBERTSON, PH.D.
HOWARD CALVIN RUMSEY, JR., PH.D.

Administrative Assistant

RUTH SELMA GOODWIN, A.B.

Research Associates

FRANK MATTHEWS LESLIE, PH.D.
JAMES RICHARD McCORD, III, PH.D.
HIRONORI ONISHI, PH.D.

Professors Emeriti

HENRY BAYARD PHILLIPS, PH.D., LL.D.
Professor of Mathematics, Emeritus
NORBERT WIENER, PH.D., SC.D.
Institute Professor, Emeritus;
Professor of Mathematics, Emeritus
RAYMOND DONALD DOUGLASS, PH.D., SC.D.
Professor of Mathematics, Emeritus; Lecturer
DIRK JAN STRUIK, PH.D.
Professor of Mathematics, Emeritus
SAMUEL DEMITRY ZELDIN, PH.D.
Associate Professor of Mathematics, Emeritus; Lecturer

MATHEMATICS

This Department offers a variety of programs to those interested in mathematics primarily as a pure science or for the additional purpose of applying it to other sciences, to fields of engineering, or to business.

THE UNDERGRADUATE CURRICULUM

Mathematics (Course XVIII)

Each undergraduate's program is arranged through continuous collaboration between the individual student and his Faculty Counselor, subject only to a minimum uniform set of Course requirements. In most cases, the undergraduate curriculum in mathematics is preparatory to further professional training at the graduate level. For this purpose each student is encouraged both to obtain a substantial grounding in each of the fundamental branches of mathematics and also to explore certain fields of application, in order to establish a basis for the selection of an appropriate field of graduate specialization.

Whatever the ultimate objective — preparation for teaching, participation in the research programs of an industrial or government-sponsored organization, or a position as consultant in a business or in a modern high-speed computation center — the immediate educational aims are to provide an understanding of a substantial part of the existing body of mathematical knowledge and an ability to impart this knowledge to others. But most important, the Department hopes to inspire a deep interest in the discovery or invention of new mathematics or in the application of mathematics to a new field.

Students wishing to work with a small group of fourth-year students under the supervision of a faculty member or to do individual work with a member of the Department may elect either to participate in a senior mathematics seminar or to write a thesis. These possibilities furnish excellent opportunities for students to develop initiative. The experience gained from active participation in a seminar conducted by a research mathematician may be particularly valuable for a student planning to pursue graduate work in any branch of mathematics.

The undergraduate Course leads to the degree of Bachelor of Science in Mathematics. The curriculum requirements for the degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 155*)					176
PHYSICS 8.031 and 8.041[1] are recommended, but PHYSICS 8.03 and 8.04 are acceptable when completed with good grades.					
DEPARTMENTAL PROGRAM					
Required subjects					
18.20	[2]LINEAR ALGEBRA	3	0	6	
18.21	ANALYSIS	3	0	9	
18.22	ANALYSIS	3	0	9	
18.24	[3]ELEMENTARY DIFFERENTIAL GEOMETRY	3	0	6	
	[4]LANGUAGE			16	
					58
Elective subjects					
Specified					
	Advanced mathematics subjects at the undergraduate or graduate level			30	
	[5]Advanced professional subjects in mathematics, science, or engineering at the undergraduate or graduate level			24	
	Senior seminar in mathematics, thesis, or advanced mathematics subject at the undergraduate or graduate level			12	
	Engineering or science subjects (8 units *not* in mathematics)			17	
					83
Unspecified					47
Total units required for the S.B. degree					364

[1] 8.041, if selected, must be followed by 8.051 (or 8.05).

[2] Any student may substitute MODERN ALGEBRA (18.26, 3–0–9) for 18.20 and 3 units of mathematics elective.

[3] Any student may substitute for 18.24 one of the following, with a corresponding adjustment of mathematics elective units: RIEMANNIAN GEOMETRY (18.242, 3–0–9); INTRODUCTION TO APPLIED MATHEMATICS (18.651, 3–0–9) and INTRODUCTION TO FLUID MECHANICS (18.60, 3–0–6); or INTRODUCTION TO APPLIED MATHEMATICS (18.651, 3–0–9) and INTRODUCTION TO ELASTICITY (18.66, 3–0–6).

[4] Any student who has taken three or more years of French, German, or Russian before coming to M.I.T., or who demonstrates to his Faculty Counselor his ability to read mathematical literature in one of these languages, may substitute 16 units of elective subjects for the language requirement.

[5] These subjects together with the 30 units of elective mathematics subjects must make up an integrated program.

As a part of the curriculum, each student is required to take the two-semester subject sequence in ANALYSIS (18.21, 18.22), and two one-semester subjects, LINEAR ALGEBRA (18.20) and ELEMENTARY DIFFERENTIAL GEOMETRY (18.24). Students wishing more work in algebra as undergraduates should take the two-semester subject sequence in MODERN ALGEBRA (18.25, 18.26) in place of 18.20 and fifteen units of mathematics electives. Similarly, the two subjects INTRODUCTION TO TOPOLOGY (18.241) and RIEMANNIAN GEOMETRY (18.242), or either of the other two combinations listed in footnote 3, may be taken in place of 18.24, with a corresponding adjustment of mathematics elective units. It is

strongly recommended that the analysis and algebra be taken in the third year. The language requirement should be completed, if at all possible, by the end of the second year.

The Department recommends that undergraduate students planning to pursue graduate work in elasticity, fluid dynamics, and related fields include the following elective subjects:

INTRODUCTION TO APPLIED MATHEMATICS (18.651, 18.652)
INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27, 18.28)
INTRODUCTION TO FLUID MECHANICS (18.60)
INTRODUCTION TO ELASTICITY (18.66)
MECHANICS I (8.711)

GRADUATE STUDY IN MATHEMATICS

On the graduate level, the Department offers programs leading to the degrees of Master of Science, Doctor of Philosophy, or Doctor of Science in Mathematics.

Students may select their programs from a broad range of subjects, descriptions of which appear elsewhere in this Catalogue. Numerous informal seminars supplement the basic program. There are also a weekly Mathematics Colloquium sponsored by M.I.T., Brandeis, and Harvard and a weekly Colloquium on Applied Mathematics and Mechanics, each of which brings guest lecturers from other institutions.

Candidates who work in the field of pure mathematics will, aside from the Minor program, ordinarily take most of their subjects in the Mathematics Department. In addition to their advanced specialization, they will be encouraged to acquire breadth by taking basic subjects in analysis, algebra, geometry, and topology.

Candidates who work in the field of applied mathematics will be encouraged to study important aspects of one or more engineering or scientific fields closely related to research in applied mathematics, in addition to their studies in mathematics.

Assistance or even collaboration in problems in pure or applied mathematics which are being investigated by members of the staff may constitute part of graduate programs.

Entrance Requirements for Graduate Study

The admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions:

Chemistry. Students who present two semesters of college work in biology, geology, meteorology, or astronomy need not present GENERAL CHEMISTRY (5.01, 5.02) or its equivalent.

Mathematics. Students will normally be expected to present an undergraduate mathematics program approximating that required of undergraduate mathematics majors.

The Graduate Degrees

MASTER OF SCIENCE IN MATHEMATICS

For the Master's degree, a student must take 96 units including THESIS (20–24 units) and four 12-unit graduate ("A") subjects offered by the Department. In addition, either as an undergraduate or as a graduate student, each student is expected to have completed four subjects (or their equivalents) from the following group:

NUMERICAL ANALYSIS (18.13)
METHODS OF APPLIED MATHEMATICS (18.15)
PROBABILITY (18.18)
LINEAR ALGEBRA (18.20)
or
MODERN ALGEBRA (18.26)
ANALYSIS (18.21, 18.22)
ELEMENTARY DIFFERENTIAL GEOMETRY (18.24)
or
RIEMANNIAN GEOMETRY (18.242)
INTRODUCTION TO TOPOLOGY (18.241)
MODERN ALGEBRA (18.25)
INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27, 18.28)
INTERMEDIATE DIFFERENTIAL EQUATIONS (18.29)
INTRODUCTION TO FLUID MECHANICS (18.60)
INTRODUCTION TO APPLIED MATHEMATICS (18.651, 18.652)
INTRODUCTION TO ELASTICITY (18.66)

Of the four subjects elected from this group, two may be counted for credit towards the Master's degree if taken while the student is a graduate student at M.I.T.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN MATHEMATICS

The general requirements for the Doctor of Philosophy and Doctor of Science degrees are those set forth in Section 3. As soon as possible after beginning graduate work, each student who plans to take a doctorate in mathematics should elect one of the following two plans of study:

Plan A. A written qualifying examination covers the material in the following topics:

ANALYSIS (18.21, 18.22)
THEORY OF FUNCTIONS (18.31, 18.32)
LINEAR ALGEBRA (18.20)
or
MODERN ALGEBRA (18.26)
ELEMENTARY DIFFERENTIAL GEOMETRY (18.24)
or
RIEMANNIAN GEOMETRY (18.242)
or
MODERN ALGEBRA (18.25)

Students in this plan will take additional subjects chosen from the Department's 12-unit graduate ("A") subjects other than those included in the qualifying examination with the privilege of substituting INTRODUCTION TO FLUID MECHANICS (18.60) *or* INTRODUCTION TO ELASTICITY (18.66) for one 12-unit subject if they wish.

Plan B. A written qualifying examination covers the material in the following topics:

NUMERICAL ANALYSIS (18.13)
INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27)
INTRODUCTION TO FLUID MECHANICS (18.60)
or
INTRODUCTION TO ELASTICITY (18.66)
INTRODUCTION TO APPLIED MATHEMATICS (18.651)
ADVANCED METHODS OF APPLIED MATHEMATICS I (18.653)
ADVANCED METHODS OF APPLIED MATHEMATICS II (18.654)

It is expected that students planning to do doctoral theses in elasticity, fluid dynamics, and related fields will in most cases elect to follow Plan B. In planning their programs such students should be guided by the following requirements and recommendations for subjects beyond those recommended for the Bachelor's degree.

Required Subjects:

THEORETICAL FLUID MECHANICS (18.61)
THEORETICAL AND APPLIED ELASTICITY (18.67)
ADVANCED METHODS OF APPLIED MATHEMATICS III (18.655)
HYDRODYNAMIC STABILITY AND TURBULENCE (18.62)
or
THEORETICAL AND APPLIED ELASTICITY (18.68)

Strongly Recommended Physics Electives:

ELECTROMAGNETIC THEORY I (8.721)
MECHANICS II (8.712)

In special circumstances a student may receive permission to work under another plan (Plan N), in which regular Course requirements and written examinations in mathematics subjects are omitted. Students admitted to this program are given occasional oral examinations on their general mathematical progress.

The Minor program may be in any field, other than mathematics, in which the Institute offers advanced work. It should be started early in the student's graduate career.

Doctoral candidates are required to demonstrate proficiency in two foreign languages, which are usually chosen from French, German, and Russian. The language requirements should also be fulfilled early in the student's program.

Before the student begins work on his thesis, he is asked to submit to the Departmental Graduate Committee a brief general outline on the proposed thesis, carrying the approval of the faculty member who is his thesis adviser. When the Committee has approved the thesis proposal, the Department names two faculty members to work with the student and his adviser. The thesis is expected to represent original research and to meet the standards ordinarily required for publication in one of the standard journals devoted to research in mathematics or in a closely allied field.

Fellowships and Assistantships

Fellowships and teaching and research assistantships are available to graduate students in mathematics. Detailed information about these opportunities may be obtained from the Department.

Department of Meteorology

HENRY GARRETT HOUGHTON, SC.D.
Professor of Meteorology; Head of the Department; Director of the Laboratory of Earth Sciences
HURD CURTIS WILLETT, PH.D.
Professor of Meteorology
JULE GREGORY CHARNEY, PH.D.
Professor of Meteorology
VICTOR PAUL STARR, PH.D.
Professor of Meteorology
JAMES MURDOCH AUSTIN, SC.D.
Associate Professor of Meteorology; Director of the Summer Session
DELBAR POULEUR KEILY, S.B.
Associate Professor of Meteorology
EDWARD NORTON LORENZ, SC.D.
Associate Professor of Meteorology
NORMAN ALTON PHILLIPS, PH.D.
Associate Professor of Meteorology
FREDERICK SANDERS, SC.D.
Associate Professor of Meteorology
GEORGE VERONIS, PH.D.
Associate Professor of Oceanography
REGINALD EDWARD NEWELL, SC.D.
Assistant Professor of Meteorology

Technical Instructor
ETHAN ALLEN MURPHY

Research Associates
PAULINE MORROW AUSTIN, PH.D.
ALAN COGSWELL BEMIS, A.B., S.M.
TAKIO MURAKAMI, SC.D.
ROBERT MAYER WHITE, SC.D.

METEOROLOGY

Meteorology is the science of the atmosphere. It is one of the earth sciences, all of which deal with the physical properties of the earth. Many of man's unsolved problems depend for their solution on increased knowledge of our physical environment. The Department's educational aim is to provide its students with a broad background in meteorology and related sciences, one which will prepare them to cope with these challenging problems of the atmosphere and the physical environment.

Undergraduate Preparation for Meteorology

The first requisite for this educational objective is a sound preparation in physics and the concomitant mathematics. Students should also acquire a broad background in the earth sciences by taking selected subjects in geology and oceanography as well as in meteorology. The stage is then set for professional specialization in meteorology.

Undergraduate students who wish to prepare for graduate work in meteorology are advised to register in Geology and Geophysics (Course XII), which is designed to provide the necessary background for graduate work in any of the earth sciences. Adequate preparation is also provided by other M.I.T. undergraduate curricula, particularly in the Departments of Physics and Mathematics. Students who are taking their undergraduate work at other institutions are advised to include in their programs the equivalent of the mathematics and physics contained in the M.I.T. curricula referred to above. Some undergraduate preparation in meteorology or oceanography is helpful but is not required.

Graduate Study in Meteorology

Emphasis in graduate training is placed on the theoretical and quantitative approach, supplemented by empirical and experimental methods. This approach is based on the conviction that the progress of meteorology depends on the quantitative application of the laws of physics to the atmosphere. However, the Department recognizes that there is equal demand for individuals who are more concerned with applications and experimental studies. Such students need to understand the implications of the theoretical developments, while the theory-oriented students need an appreciation of the observational material.

Formal subjects of instruction are offered in all of the principal areas of meteorology. Subjects commonly taken by graduate students include:

19.14	LONG-RANGE WEATHER FORECASTING
19.22	METEOROLOGICAL INSTRUMENTS
19.34	STATISTICAL METHODS IN METEOROLOGY
19.45	SYNOPTIC METEOROLOGY III
19.46	NUMERICAL WEATHER PREDICTION
19.53	SYNOPTIC LABORATORY II
19.64	DYNAMIC METEOROLOGY II
19.67	PLANETARY FLUID DYNAMICS
19.71	RADAR METEOROLOGY
19.72	PHYSICAL METEOROLOGY

As this list suggests, facilities for instruction and research are available in all of the principal areas of meteorology. There are several radar systems and associated equipment together with a large and comprehensive file of radar data. Current weather data covering North America, Western Europe, and the adjacent oceans are available on teletypewriter circuits. Extensive files of weather data are available for most areas of the world; much of this is already in form for use on modern computing machines, and students have access to desk computers, I.B.M. card equipment, and the high-speed computing facilities of the Computation Center.

The Meteorological Instrumentation Laboratory contains standard and specialized instrumentation and special test equipment. Laboratory facilities are available for research in physical meteorology, especially in the fields of cloud and precipitation physics. The facilities of the Woods Hole Oceanographic Institution are available to qualified students who wish to undertake field or laboratory work in oceanography or marine meteorology.

The Department conducts an extensive program of sponsored research. Graduate students are often able to participate in this program as either full-time or part-time research assistants. Such active participation is considered a valuable supplement to the formal academic program and also provides some financial assistance.

The area surrounding Cambridge contains a number of institutions engaged in research in meteorology and related fields, such as the Air Force Cambridge Research Laboratories, the Woods Hole Oceanographic Institution, the Blue Hill Meteorological Observatory of Harvard University, and the Boston offices of the United States Weather Bureau. Close contact with the scientific personnel of these institutions is maintained through joint seminars and symposia as well as by more informal means.

Graduate Study in Oceanography

In cooperation with the Department of Geology and Geophysics and the Woods Hole Oceanographic Institution, a graduate program in oceanography is now being offered. The equations that describe the motions of the atmosphere are the same as those for the oceans. The oceans and the atmosphere are closely coupled both mechanically and thermally so that they must often be considered as parts of a single system. Many of the subjects of instruction in meteorology are thus directly applicable to oceanography. Subjects in oceanography are now offered and more are planned. Certain subjects given by the Department of Geology and Geophysics are also directly applicable to the geological aspects of oceanography. Several staff members of the Woods Hole Oceanographic Institution hold part-time faculty appointments at M.I.T. They give formal subjects and are also available for individual consultation and serve as thesis advisers. Arrangements may be made for M.I.T. graduate students to use the excellent facilities for oceanographic research at Woods Hole.

Entrance Requirements for Graduate Study

Although an undergraduate program of the type described above is considered the best preparation for graduate study, it is not required; graduates of recognized institutions who present evidence of sound preparation in physics and mathematics and who meet the general requirements for admission to the Graduate School (see Section 3 of this Catalogue) may be admitted. However, training substantially equivalent to that provided by SYNOPTIC METEOROLOGY I (19.43), DESCRIPTIVE METEOROLOGY (19.02) and INTRODUCTION TO THEORETICAL METEOROLOGY (19.601) will make it possible for students to pursue a more advanced program of studies immediately after admission. Applicants with no previous training in meteorology will generally be required to take these subjects during their graduate study and therefore must expect to be in residence for a somewhat longer period.

The advanced subjects offered by the Department lead to the degrees of Master of Science in Meteorology, Master of Science in Oceanography, Doctor of Philosophy in Meteorology, Doctor of Philosophy in Oceanography, and Doctor of Science in Meteorology.

The Graduate Degrees

MASTER OF SCIENCE IN METEOROLOGY OR IN OCEANOGRAPHY

The 72 units of graduate ("A") subjects required for the Master of Science degree 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 the field is discouraged. There are no foreign language requirements for the degree.

DOCTOR OF PHILOSOPHY IN METEOROLOGY OR IN OCEANOGRAPHY AND DOCTOR OF SCIENCE IN METEOROLOGY

The general requirements for the degrees of Doctor of Science and Doctor of Philosophy are given in Section 3. Candidates for the doctorate in meteorology or in oceanography are required to demonstrate their ability to read scientific literature in English and in two other modern languages, one of which must be German or Russian. The second language must be one in which there is important meteorological or oceanographic literature. Among others, German or Russian (if not chosen as the first language), French, Norwegian, Swedish, Spanish, and Japanese satisfy this requirement.

Assistantships and Fellowships

The Department offers a limited number of research and teaching assistantships each year. Research assistants are assigned to work on one of the many research projects in the Department. Teaching assistants may be assigned to assist in laboratory instruction or to the preparation of teaching materials and the grading of papers. Information concerning these appointments may be obtained from the Head of the Department. The Department offers a few predoctoral fellowships in the atmospheric sciences and oceanography. Announcements and application forms are available around the first of the year and may be obtained from the Head of the Department.

Department of Nutrition, Food Science and Technology

NEVIN STEWART SCRIMSHAW, PH.D., M.D.
Professor of Nutrition; Head of the Department

SAMUEL ABRAHAM GOLDBLITH, PH.D.
Professor of Food Science and Technology; Executive Officer

ROBERT SAMUEL HARRIS, PH.D.
Professor of Nutrition

ALFRED EDWIN HARPER, PH.D.
Professor of Nutrition

CECIL GORDON DUNN, PH.D.
Associate Professor of Industrial Microbiology

JOHN THEODORE ROOSEVELT NICKERSON, PH.D.
Associate Professor of Food Science and Technology

DONALD MORGAN WATKIN, M.D.
Associate Professor of Nutrition

STANLEY ELY CHARM, SC.D.
Assistant Professor of Food Science and Technology

SANFORD ARTHUR MILLER, PH.D.
Assistant Professor of Nutrition

EMILY LIPPINCOTT WICK, PH.D.
Assistant Professor of Food Science and Technology

LOUIS CHARLES FILLIOS, SC.D.
Assistant Professor of Nutrition

MARCUS KAREL, PH.D.
Assistant Professor of Food Science and Technology

JEROME ARNOLD URAM, SC.D.
Assistant Professor of Food Toxicology

Lecturers

CHARLES N. FREY, PH.D., D.SC.
WILLIAM A. GEISLER
PAUL MAY JACOBS, A.B.
ARNOLD JOHN LEHMAN, PH.D., M.D.
JOHN HOWARD RUST, D.V.M., PH.D.
BERNARD FRANCIS TRUM, D.V.M.
RAY B. WAKEFIELD, CH.E.
JAMES ROBERT WILSON, M.D.

Instructors

PHILLIP ISSENBERG, S.B.
RICHARD ISAAC MATELES, SC.D.

Research Associates

ROBERT JACOB BOUTHILET, PH.D.
NORMAN SEYMOUR DAVIS, M.S.
HECTOR JEAN HONORÉ DE MUELENAERE, PH.D.
HENRY ADAM DYMSZA, PH.D.
JOHAN EDUARD HOFF, M.S.
JOSEPH JOHN LICCIARDELLO, PH.D.
ALEXANDER KENNETH LOUGH, PH.D.
EDMUND BURTON MASUROVSKY, PH.D.
MABEL CRAWFORD MERRITT, B.S.
JUNYA MIZUTANI, PH.D.
ABRAHAM EDWARD NIZEL, D.M.D., M.S.D.
PHILIP MORRISON RICHARDSON, PH.D.
LOUIS JOSEPH RONSIVALLI, S.M.
GERALD SILVERMAN, PH.D.
RICHARD FRANK ZIMPEL, S.B.

NUTRITION AND FOOD SCIENCE AND TECHNOLOGY

The science of nutrition encompasses all aspects of the quantitative and qualitative needs of living organisms for essential nutrients from food and the way in which these nutrients are utilized in metabolic processes. Environmental stress, disease, emotional factors and genetic constitution, and the form and proportions of the essential nutrients in food all influence these requirements. Nutrition is thus one of the broadest and most inclusive of the life sciences, requiring the knowledge and techniques of the chemist, biochemist, physicist, engineer, physiologist, physician, specialist in public health, statistician, and social scientist. Nutrition cannot be separated from food science, which deals with the nutrient content and value of foods and the presence in them of non-nutrient but biologically active factors. Food science in turn is the basis for food technology, which is of steadily increasing importance for the improvement of the nutritive value, availability, and convenience of food and for meeting the challenge of feeding the world's growing population.

Nutrition is still a pioneering field only on the threshold of obtaining adequate knowledge of optimal nutritional needs for growth, development, physical and mental activity, resistance to infectious disease, and prevention of degenerative diseases in man. Furthermore, the spectacular advances of the last two decades in the processing, packaging, and distribution of food only foreshadow the changes which must come about in the handling of man's food supply in the decades immediately ahead if the needs of developed and developing countries alike are to be met more adequately.

RESEARCH AND TEACHING ACTIVITIES

The Department of Nutrition, Food Science and Technology includes workers trained in biology, biochemistry, animal nutrition, medicine, and public health as well as in food analysis, food processing, food and flavor chemistry, industrial and food microbiology, food technology, food engineering, and food toxicology. All of these persons direct their efforts toward understanding and meeting man's food needs. Such a broad and integrated department makes possible the type of interdisciplinary training and investigation required for understanding modern problems of human nutrition and making practical contributions toward their solution.

The Department is cooperating with the Food and Agriculture Organization and the World Health Organization of the United Nations and has established joint research and training programs with the Institute of Nutrition of Central America and Panama (INCAP) in order to contribute more directly to the solution of the nutritional problems of technically underdeveloped areas and to insure that its graduates also have adequate orientation and training for this purpose. It is thus becoming a major factor in the world-wide efforts to insure that all people everywhere are adequately fed. Technical manpower is urgently needed for this purpose, and the broad nature of the Department and the varied backgrounds of its staff provide a unique opportunity for training for this type of research and service.

The Department has already pioneered in advanced research in food technology, nutritional biochemistry, industrial microbiology, flavor evaluation, and the radiation sterilization of foods. It has also contributed important knowledge of many types of chemical, physical, and biological agents which are involved in the protection of raw and processed food products, and of the basic reactions and metamorphoses through which foods pass in their development, maturation, and fabrication. It has been concerned with developing new products and adjusting them to successful manufacture and quality control and has designed machinery and equipment to prepare foods for human consumption.

The Department is now developing programs which involve the study of amino acid metabolism and requirements, lipid metabolism in relation to chronic disease, the effects of infection and physical and mental stress on nutrient requirements and nutritional status, the role of ingested nutrients in organic development and function, the nature and selective role of mechanisms of absorption of specific nutrients, the involvement of nutrients in metabolic cycles, the clinical and biochemical evaluation of nutritional status, and the nutrition of patients with cancer and other chronic disease.

In its cooperative programs with INCAP, the Department is also investigating the characteristics and treatment of extreme deficiency states such as Kwashiorkor and Marasmus, the role of intestinal parasites and other enteric and systemic infections in the development of nutritional disease, the elaboration of low-cost, protein-rich foods for use in technically underdevel-

oped areas, and the biological evaluation of the food resources of such areas. The Department is also expanding its studies of the biological effects of the many pharmacologically active substances which occur naturally in foods or enter as accidental contaminants or intentional additives.

While the Life Sciences curriculum (Course VII) gives undergraduates an opportunity to major in either nutrition or food science and technology, most of the specialized training in this field must be obtained at the graduate level after thorough preparation in the basic sciences involved in nutrition and in food science. The Department is thus interested in giving to biochemists, physiologists, physicians, technologists, and engineers the advanced training necessary for leadership in the study and solution of problems of human nutrition and in foods. A thorough background in the physical and natural sciences is essential.

GRADUATE STUDY IN NUTRITION, FOOD SCIENCE AND TECHNOLOGY

The Department of Nutrition, Food Science and Technology offers advanced programs leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Nutrition; and Master of Science, Doctor of Philosophy, and Doctor of Science in Food Science and Technology. It also offers graduate programs in Biochemical Engineering leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Biochemical Engineering.

Many fields of research are open to graduate students, including such varied problems as nutritional biochemistry, animal nutrition, metabolism, clinical nutrition, nutrient requirements and interrelationships, nutritional endocrinology, food and tissue nutrient content, food toxicology, biochemical engineering, food microbiology, food processing, food engineering, food and flavor chemistry, and sensory stimuli and their role in nutrition and food processing. The Department is well equipped for research in these areas; its facilities include modern animal laboratories; well-equipped physicochemical and biochemical laboratories; and processing laboratories for thermal, chemical, dehydration, and radiation processing research.

COOPERATIVE PROGRAM WITH THE INSTITUTE OF NUTRITION OF CENTRAL AMERICA AND PANAMA

Under a cooperative program with the Institute of Nutrition of Central America and Panama, a limited number of students with the necessary prerequisites are able to carry out research work for the degree programs while in residence at the Institute in Guatemala. This offers a special opportunity for studies of serious nutritional problems characteristic of technically underdeveloped areas.

Physicians who are candidates for either the degree of Master of Science in Nutrition or Doctor of Philosophy or Doctor of Science in Nutrition will ordinarily be required to take subjects in public health nutrition, clinical nutrition, and evaluation of nutritional status which are given in Guatemala during the summer.

Entrance Requirements for Graduate Study

The general requirements for admission to the Graduate School are given in Section 3 of this Catalogue. Applicants for advanced study in the Department of Nutrition, Food Science and Technology are required to meet, as prerequisites, the general equivalent of the undergraduate program in the Life Sciences. Graduates from accredited institutions who present evidence of a high order of scholarship in related professional fields may be permitted either equivalent substitutions for these prerequisites or the privilege of taking examinations for advanced standing in the case of deficiencies.

The Master of Science Degrees

The general requirements for all Master's degrees are set forth in Section 3.

MASTER OF SCIENCE IN NUTRITION; MASTER OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY

Students who have a Bachelor of Science degree in the Life Sciences at M.I.T. or who have an equivalent background may attain a Master of Science degree in Nutrition or in Food Science and Technology in one year.

While the program for the degree is extremely flexible, the following graduate subjects are strongly recommended for the Master of Science degree in Nutrition:

PRINCIPLES OF FOOD AND TISSUE ANALYSIS (20.32T)
ADVANCED HUMAN NUTRITION (20.36T)
SEMINAR IN NUTRITION, FOOD SCIENCE AND TECHNOLOGY (20.61)

For the Master of Science degree in Food Science and Technology, the following graduate studies are strongly recommended:

PRINCIPLES OF FOOD AND TISSUE ANALYSIS (20.32T)
ADVANCED FOOD SCIENCE AND TECHNOLOGY (20.51T)
SEMINAR IN NUTRITION, FOOD SCIENCE AND TECHNOLOGY (20.61)

Subjects in chemistry, biochemistry, physics, mathematics, or chemical engineering are recommended according to each individual case.

MASTER OF SCIENCE IN BIOCHEMICAL ENGINEERING

For the Master of Science in Biochemical Engineering, greater emphasis is placed on electives in biochemistry, microbiology, chemistry of microorganisms, chemical engineering, or industrial management, again depending on the individual student.

The Doctorates

The curriculum for the doctorate in either nutrition or in food science and technology offers opportunity for advanced study and research in these areas.

Candidates for doctorates are required to demonstrate proficiency in two foreign languages; these are chosen upon consultation between each student and his Graduate Registration Officer.

DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE IN NUTRITION; DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY

The choice of subjects in programs for the degree of Doctor of Philosophy or Doctor of Science in Nutrition and for the degree of Doctor of Philosophy or Doctor of Science in Food Science and Technology depends on each student's background, his aptitudes, and his future plans. The Department Committee on Graduate Students assists with the planning of programs.

Students are expected to prepare themselves early in their graduate programs for qualifying examinations for the doctorate. Following successful completion of these examinations, comprehensive written and oral general examinations are taken by each student. These test his understanding of the fundamentals of modern nutrition, food science, food technology, and food engineering, as well as of the basic related scientific disciplines. They also test his ability to utilize these basic sciences in the many problems of modern nutrition, food science, and food technology.

DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE IN BIOCHEMICAL ENGINEERING

No particular sequence of graduate subjects is specified for the degree of Doctor of Philosophy or Doctor of Science in Biochemical Engineering. Advanced studies are recommended in the fields of biochemistry, microbiology, enzymology, and chemical engineering, coordinated with studies of problems in the modern fermentation industry. Programs must be approved by an interdepartmental committee which includes representatives from the Departments of Nutrition, Food Science and Technology; Biology; and Chemical Engineering. Doctoral examinations, which are prepared and conducted by this committee, follow the same pattern described above for nutrition, food science and technology and include qualifying and general examinations.

Assistantships

The Department offers a limited number of graduate research assistantships for work in the areas described above under "Graduate Study in Nutrition, Food Science and Technology." Applications — accepted only from admitted graduate students — should be made to the Head of the Department.

Department of Physics

NATHANIEL HERMAN FRANK, SC.D. (*Absent*)
Professor of Physics; Head of the Department

WILLIAM WEBER BUECHNER, PH.D., SC.D.
Professor of Physics; Acting Head of the Department

GEORGE GRAHAM HARVEY, PH.D.
Professor of Physics; Executive Officer; Associate Director of the Research Laboratory of Electronics

GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D., D.ENG.
Professor of Physics; Dean of the School of Science

JOHN CLARKE SLATER, PH.D., SC.D.
Institute Professor; Harry B. Higgins Professor of the Solid State

PHILIP MCCORD MORSE, PH.D., SC.D.
Professor of Physics; Director of the Computation Center; Director of the Operations Research Center

BERTRAM EUGENE WARREN, SC.D.
Professor of Physics

HANS MUELLER, D.SC.
Professor of Physics

WAYNE BUCKLES NOTTINGHAM, PH.D.
Professor of Physics

ROBLEY DUNGLISON EVANS, PH.D.
Professor of Physics

JERROLD REINACH ZACHARIAS, PH.D.
Professor of Physics

BRUNO BENEDETTO ROSSI, PH.D.
Professor of Physics

VICTOR FREDERICK WEISSKOPF, PH.D. (*Absent*)
Professor of Physics

ALBERT GORDON HILL, PH.D.
Professor of Physics

WILLIAM PHELPS ALLIS, SC.D.
Professor of Physics

MARTIN DEUTSCH, PH.D.
Professor of Physics

MILTON STANLEY LIVINGSTON, PH.D.
Professor of Physics

HERMAN FESHBACH, PH.D.
Professor of Physics

CLIFFORD GLENWOOD SHULL, PH.D.
Professor of Physics

GEORGE EDWARD VALLEY, JR., PH.D.
Professor of Physics

BERNARD TAUB FELD, PH.D.
Professor of Physics; Chairman of the Directing Committee, Laboratory for Nuclear Science

FRANCIS EUGENE LOW, PH.D. (*Absent*)
Professor of Physics

FRANCIS LEE FRIEDMAN, PH.D.
Professor of Physics

DAVID HENRY FRISCH, PH.D.
Professor of Physics

MALCOM WOODROW PERSHING STRANDBERG, PH.D. (*Absent*)
Professor of Physics

LASZLO TISZA, PH.D.
Professor of Physics

FELIX MARC HERMANN VILLARS, D.SC.
Professor of Physics

PETER THEODORE DEMOS, PH.D.
Professor of Physics; Associate Director of the Laboratory for Nuclear Science

ALAN NORDBY HOLDEN, PH.D.
Professor of Physics (Visiting)

SILVAN SAMUEL SCHWEBER, PH.D.
Professor of Physics (Visiting)

CHARLES HARD TOWNES, PH.D., D.LITT.
Professor of Physics; Provost

ANTHONY PHILIP FRENCH, PH.D.
Professor of Physics (Visiting)

SANBORN CONNER BROWN, PH.D.
Associate Professor of Physics

KARL UNO INGARD, PH.D.
Associate Professor of Physics

WILLIAM LESTER KRAUSHAAR, PH.D.
Associate Professor of Physics

DAVID ORVILLE CALDWELL, PH.D.
Associate Professor of Physics

JOHN GORDON KING, PH.D.
Associate Professor of Physics

EMANUEL MAXWELL, PH.D.
Associate Professor of Physics (Visiting)

HARALD ANTON ENGE, DR.PHIL.
Associate Professor of Physics

LOUIS SHREVE OSBORNE, PH.D.
Associate Professor of Physics

MICHAEL PETER BARNETT, PH.D.
Associate Professor of Physics

GEORGE WHIPPLE CLARK, PH.D.
Associate Professor of Physics

ARTHUR KENT KERMAN, PH.D. (*Absent*)
Associate Professor of Physics

GEORGE FRED KOSTER, PH.D.
Associate Professor of Physics

GEORGE BERNARD BENEDEK, PH.D.
Associate Professor of Physics

KERSON HUANG, PH.D. (*Absent*)
Associate Professor of Physics

KENNETH ALAN JOHNSON, PH.D.
Associate Professor of Physics

EARL LEONARD LOMON, PH.D.
Associate Professor of Physics (Visiting)

STANISLAW OLBERT, PH.D.
Associate Professor of Physics

IRWIN ABRAHAM PLESS, PH.D.
Associate Professor of Physics

JAMES HAMMOND SMITH, PH.D.
Associate Professor of Physics (Visiting)

JOHN FRANCIS COCHRAN, PH.D.
Assistant Professor of Physics

WILLIAM MERRILL WHITNEY, PH.D.
Assistant Professor of Physics

LEE GRODZINS, PH.D.
Assistant Professor of Physics

RUDOLF WILHELM BAUER, PH.D.
Assistant Professor of Physics

WILLIAM BERTOZZI, PH.D.
Assistant Professor of Physics

PAUL GERARD FEDERBUSH, PH.D.
Assistant Professor of Physics

JEROME ISAAC FRIEDMAN, PH.D.
Assistant Professor of Physics

GEORGE BEKEFI, PH.D.
Assistant Professor of Physics

ARON MYRON BERNSTEIN, PH.D.
Assistant Professor of Physics

KENNETH WILLIAM BILLMAN, PH.D.
Assistant Professor of Physics

HENRY WAY KENDALL, PH.D.
Assistant Professor of Physics

ALAN JAY LAZARUS, PH.D.
Assistant Professor of Physics

LAWRENCE ROSENSON, PH.D.
Assistant Professor of Physics

FRANK SCHERB, PH.D.
Assistant Professor of Physics

KENNETH GORDON McCRACKEN, PH.D.
Assistant Professor of Physics

Lecturers

HERBERT SAGE BRIDGE, PH.D.
Research Physicist

FREDERIC JOHN EPPLING, PH.D.
Research Physicist

GERHARD EMIL FISCHER, PH.D.

DAVID ALLEN HILL, PH.D.

PAUL DAVID LUCKEY, PH.D.

CHARLES PHILIP SARGENT, PH.D.

Instructors

RICHARD HOUZET LEMMER, D.SC., PH.D.

LEE WALLACE DEAN, III, PH.D.

EDWIN KASHY, PH.D.

CARL MARX SHAKIN, PH.D.

RAYMOND ANGELO ALVAREZ, JR., PH.D.

HALE VAN DORN BRADT, PH.D.

DAVID HOLMES DOUGLASS, JR., PH.D.

JOHN ROBERT ERSKINE, PH.D.

EDWARD ALAN PHILLIPS, S.B.

Research Associates

LEE CARRINGTON BRADLEY, III, D.PHIL.

PAUL FENIMORE COOPER, JR., PH.D.

Professor Emeritus

ARTHUR COBB HARDY, SC.D.
Professor of Optics and Photography, Emeritus

PHYSICS

The progress of physics during the first half of the twentieth century has been unprecedented in the history of science. The great advances of quantum theory and the theory of relativity have enabled physics to move far beyond the conventional areas of mechanics, sound, heat, light, electricity, and magnetism; these advances have led to a remarkably complete understanding of the structure of atoms, molecules, and matter in bulk, of electronics and gas discharges, and of atomic and molecular spectra and the nature of light. The discovery of radioactivity, of cosmic rays and "strange" particles, and of nuclear fission and fusion has led to an increased understanding of the atomic nucleus and its structure. The rapidly expanding field of high-energy physics provides all the excitement and challenge of the unknown and partially understood which have characterized the periods of great discoveries of physics in the past. As a result of recent work, the fundamental laws governing the nature of matter and energy are partly understood, and great progress in these matters is bound to be made in the foreseeable future.

Along with this remarkable advance in basic knowledge has come, with unprecedented speed, a widespread application of new principles and methods to practical problems in a variety of fields. New methods of electronics have revolutionized communications and instrumentation and have led to new high-speed digital computers, which find everwidening realms of applicability. Relatively old fields such as fluid dynamics have become revitalized. Physical tools acquired from researches in X-ray, electron, and neutron diffraction, electron microscopy, and modern optical spectroscopy have opened entirely new experimental approaches to problems in chemistry, metallurgy, and biology, as well as in technology as a whole. Applied nuclear physics, with its use of artificial radioactive tracers, plays a similar role in a multitude of scientific and technological disciplines. The day has passed when physics, or any branch of it, can be considered as merely of academic interest. The broad knowledge of physical principles and methods prepares a man uniquely and powerfully to tackle new problems of industry and modern technology.

The Physics Department is aware of the vital importance of maintaining an active research program of highest quality in the pursuit of fundamental knowledge. Excellent research facilities are available, additional facilities are being developed, and extensive research programs are carried on in a large number of fields of active interest. Interdepartmental research laboratories, such as the Laboratory for Nuclear Science, the Research Laboratory of Electronics, and the Spectroscopy Laboratory serve to correlate the research in various departments in these fields; their facilities are available to students in physics as well as to the staff of the Department. Electronuclear machines capable of producing high-energy particles are available in the Laboratory for Nuclear Science; these include a cyclotron, electrostatic generators, a linear accelerator, and an electron synchrotron. A new 6 Bev electron accelerator is now being constructed under the joint auspices of Harvard University and M.I.T.; the facilities of this Cambridge Electron Accelerator will be available to graduate students in physics. There are active research programs in nuclear structure, cosmic rays, high energy physics, and applied radioactivity. A new research program in space physics has recently been started.

The Research Laboratory of Electronics provides unequalled facilities for research in microwave electronics and in related fields of physics utilizing these techniques. The Laboratory is equipped to produce very high magnetic fields and very low temperatures, and these are used extensively in research programs. Fundamental work in the physics of plasmas is carried on in this Laboratory.

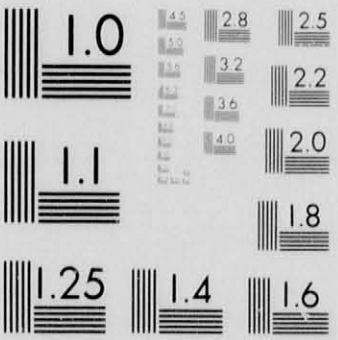
The Spectroscopy Laboratory is unique in the field of spectroscopic measurements and analysis and harbors programs of interest to physics. Research is carried on actively in solid state and molecular theory, physical optics, X-ray diffraction and crystal structure, electron microscopy, and the structure of dielectrics.

A research program in neutron diffraction is in progress, using the nuclear reactor operated by the Department of Nuclear Engineering; and other research programs using this important facility are contemplated.

THE UNDERGRADUATE CURRICULUM

Physics (Course VIII)

The Course leads to the degree of Bachelor of Science in Physics. The curriculum requirements for the degree are given in the next column.



MICROCOPY RESOLUTION TEST CHART
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M.I.T. ANNUAL CATALOGUES AND BULLETINS
1961/62

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				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 155*)				**176**
PHYSICS 8.031 and 8.041[1] are prescribed but PHYSICS 8.03 and 8.04 are acceptable, when completed with good grades, in the case of students transferring to Course VIII.				
DEPARTMENTAL PROGRAM				
Required subjects				
6.14	ELECTRONIC NETWORKS AND DEVICES	4	0 8	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0 6	
8.05	[2]PHYSICS OF ATOMS AND MOLECULES I	4	0 8	
8.08	ELECTRONICS	4	0 6	
8.09T	EXPERIMENTAL ATOMIC PHYSICS I	0	6 6	
8.06	[2]PHYSICS OF ATOMS AND MOLECULES II	4	0 8	
8.10T	EXPERIMENTAL ATOMIC PHYSICS II	0	4 4	
8.711	MECHANICS I	4	0 8	
8.11	[3]EXPERIMENTAL PHYSICS AND THESIS	2	10 4	
8.72	ELECTROMAGNETIC RADIATION	4	0 8	
8.07	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0 6	
				125
[4]Elective subjects				
Specified				
	One additional subject in mathematics		3 0 6	
	One subject in chemistry, preferably one of the following:			
5.41	ORGANIC CHEMISTRY I		4 0 4	
5.60	PHYSICAL CHEMISTRY		3 0 6	
5.64	STRUCTURAL CHEMISTRY		3 0 5	
				17–18
Unspecified (minimum)				**42–41**
Total units required for the S.B. degree				**360**

[1] 8.041 must be followed by 8.05 (or 8.051).
[2] In special cases the sequence 8.051 and 8.052 or 8.053 will be accepted in place of 8.05 and 8.06.
[3] Students will arrange with the instructor in charge of 8.11 the number of units in this subject to be assigned to thesis. A thesis of at least 12 units is required for graduation.
[4] It is recommended that, in general, a student take no more than 24 units of elective subjects in the second year, 21 units in the third year, and 32 in the fourth year.

The undergraduate curriculum in physics offers students the opportunity of acquiring basic competence in the fundamentals of both experimental and theoretical physics. The offerings are of sufficient depth and breadth so that the Course VIII graduate is well equipped either to build a career in the field of applied physics in industry or to enter a graduate program in preparation for more advanced professional work. The central core of requirements for the Bachelor's degree, as listed in the subsequent tabulation of departmentally prescribed subjects and elective subjects, is designed not only to accomplish the foregoing objective but also to allow each student to select a considerable variety of subjects and to proceed at the pace best suited to his individual desires and capabilities.

The curriculum for the first year is described on pages 38–39.

In the second year it is recommended that the student take ELECTRONIC NETWORKS AND DEVICES (6.14) in the second term in order to acquire familiarity with and a knowledge of electronic devices which will be useful in his subsequent laboratory subjects. Omission of this subject from a student's second-year curriculum will necessitate added effort on his part in connection with his third-year laboratory work. Adequate elective time is made available in the second year — something of the order of 18 units in the first term and 6 to 9 units in the second term (assuming that 6.14 is taken in this term) — and for most students it is wise to plan to satisfy the departmental requirement of one subject in chemistry during this year. It is suggested that this chemistry requirement be satisfied by taking ORGANIC CHEMISTRY I (5.41), PHYSICAL CHEMISTRY (5.60), *or* STRUCTURAL CHEMISTRY (5.64).

The departmentally prescribed subjects 8.05, 8.06, 8.08, 8.09T, 8.10T, and 18.05 are normally taken in the third year. In addition, students generally find it to their best advantage to take the prescribed mathematics elective subject subsequent to 18.05. Students interested in molecular and solid state physics may prefer to substitute INTRODUCTION TO SOLID-STATE PHYSICS (8.44) for ELECTRONICS (8.08). Part of the elective time available in the second term of the third year may be used effectively in a variety of ways. For example, a student may take 8.07 or 8.72 to obtain greater flexibility in his fourth-year program; he may elect INTRODUCTION TO NUCLEAR PHYSICS (8.053) if his interests lie in this direction; or he may take INTRODUCTION TO SOLID-STATE AND MOLECULAR PHYSICS (8.052) if he wishes to continue further along these lines. Each student is urged to explore with his Faculty Counselor various possibilities of electing those subjects which are best suited to his individual needs at this stage of his studies.

In the fourth year students generally undertake 8.11, 8.07, and the theoretical sequence 8.711 and 8.72. A relatively large amount of elective time thus becomes available in this year and can be used effectively in a wide variety of ways. EXPERIMENTAL PHYSICS AND THESIS (8.11) is designed to enable the student to come face to face with the challenge of exploring a problem in experimental physics in the same spirit in which experimental research is done by

the professional physicist. Every attempt is made to give the individual student maximum freedom in the choice of the nature of the problem undertaken, the amount of time which may be devoted to this effort, and the environment in which this experimental work is to be carried on.

In the specific choice of a curriculum for Course VIII, each student should keep in mind the following essential pattern of subjects falling into two major categories:

1. An orderly sequence of laboratory subjects culminating in 8.11 to enable him to obtain the competence in experimental work which he needs to embark successfully on his future professional career.
2. A corresponding sequence of lecture (and recitation) subjects. In this sequence the theoretical subjects 8.711 and 8.72 are designed to recapitulate and organize the essentials of classical theoretical physics and also to provide a solid theoretical springboard for much of the student's future education in physics.

GRADUATE STUDY IN PHYSICS

The Department of Physics offers graduate work leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science in Physics. No stated curriculum of subjects of instruction is required for any of these degrees; instead, individual curricula are chosen in consultation with the Registration Officer, in accordance with certain broad principles.

Subjects of study include work in almost all of the experimental fields described in the paragraphs above, and in the various branches of theoretical physics as well. Graduate students are expected to gain real familiarity with several of the branches of physics, not merely with one specialty. They will be well prepared for either academic work or industrial research, since the training includes a broad and thorough understanding of both the fundamentals of physics and its advanced applications.

A number of half-time research or teaching assistantships for graduate students become available each year. Application forms and further information may be obtained from the Graduate Registration Officer, Department of Physics.

Entrance Requirements for Graduate Study

The general requirements are those given in Section 3 of this Catalogue. The following subjects or their equivalents are also required but are not credited in fulfillment of degree requirements:

PHYSICS OF ATOMS AND MOLECULES I AND II (8.05, 8.06)
STATISTICAL MECHANICS AND THERMODYNAMICS (8.07)
ELECTRONICS (8.08)

Twenty-four units in the following advanced undergraduate subjects may be credited toward, and are required for, advanced degrees:

EXPERIMENTAL PHYSICS AND THESIS (8.11)
MECHANICS I (8.711)
ELECTROMAGNETIC RADIATION (8.72)

Deficiencies in subjects required for admission or for advanced degrees may be removed while the student is engaged in graduate work.

The Graduate Degrees

MASTER OF SCIENCE IN PHYSICS

In addition to general requirements set forth in Section 3, a reading examination in scientific French, scientific German, or scientific Russian is required.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE IN PHYSICS

The degree of Doctor of Philosophy or Doctor of Science requires examination for reading knowledge of scientific literature in two of the following languages: French, German, and Russian.

The student is expected to take graduate subjects to prepare himself for the General Examination, but there are no stated required subjects.

OTHER ACADEMIC DEPARTMENTS AND OFFICES

DEPARTMENT OF AIR SCIENCE

JACK DWYER ALEXANDER, M.A., M.B.A.
Major, U. S. Air Force
Professor of Air Science; Head of the Department

ROBERT CHARLES SHOEMAKER, B.S.
Captain, U. S. Air Force
Associate Professor of Air Science

LEO BRACHTENBACH, B.S.
Captain, U. S. Air Force
Assistant Professor of Air Science

DAVID ANDREW SENA, B.S.
Captain, U. S. Air Force
Assistant Professor of Air Science

Instuctors

DONALD TITUS TATTERFIELD
Staff Sergeant, U. S. Air Force

ROBERT EARLE GROTE
Technical Sergeant, U. S. Air Force

THEODORE MULFORD DOAN, JR.
Technical Sergeant, U. S. Air Force

CENTER FOR INTERNATIONAL STUDIES

MAX FRANKLIN MILLIKAN, PH.D.
Director

DONALD LAWRENCE MORTON BLACKMER, M.A.
Assistant Director

DRAMA

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Director of Drama

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Associate Professor of Military Science

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Associate Professor of Military Science

Bandleader

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Major, Infantry, Retired

Instructors

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Master Sergeant, U. S. Army

THOMAS AQUINAS GORMLEY
Sergeant First Class, U. S. Army

EUGENE JOHN BARTECCHI
Sergeant First Class, U. S. Army

TEOFILO MORENO
Sergeant First Class, U. S. Army

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Sergeant First Class, U. S. Army

Administrative Assistant

EDGAR FREDERICK RIQUIER
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JOHN DEAN CORLEY, JR., M.MUS.
Assistant Director of Music

VICTOR HENRY MATTFELD, PH.D.
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Associate Professor of Naval Science

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Assistant Professor of Naval Science

JERRY BERNARD CHICHESTER, A.B.
Lieutenant (junior grade), U. S. Navy
Assistant Professor of Naval Science

Instructors

WILLIAM HOWARD CLARK, JR.
Chief Storekeeper, U. S. Navy

PETER JOHN NERIS
Master Gunnery Sergeant, U. S. Marine Corps

ROBERT JAMES EMBRY, B.S.
Yeoman First Class, U. S. Navy

MILLARD LOWELL SCUDDER
Yeoman Second Class, U. S. Navy

DESCRIPTIONS OF SUBJECTS

The subjects and descriptions given in this Section are subject to change. The final list of subjects to be given in 1961–62 will be published with the class schedules prior to the beginning of each term.

"T" at the end of a subject number indicates that (1) a change has been made in the content or units of the subject or (2) the number was previously assigned to a different subject.

"J" at the end of a subject number indicates that the subject is a joint offering of more than one department.

"(A)" following the name of a subject indicates that it is an approved subject for a graduate degree.

"(R)" following the name of a subject indicates that it is restricted to special groups because of content; all subjects open only to special groups are so noted at the end of the description of the subject.

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

1. The number(s) of prerequisite subjects, if any. Numbers in italics indicate subjects which may be taken simultaneously with the subject described.
2. The year classification (and term) for which the subject is normally scheduled. This is indicated as follows: "1" is a first-year subject only, and not accepted for upperclass credit; "U" is an undergraduate subject above the first year; "G" is a graduate subject.
3. The time distribution of the subject, showing in sequence the units allotted to: recitation and lecture; laboratory, drawing, or field work; and preparation. Each unit represents 15 hours of work. The total unit credit for a subject is obtained by adding together all the units shown. One unit of recitation or lecture credit, and two units of laboratory or drawing credit, are each equivalent to one semester hour.

"*Arr.*" indicates that time units are specially arranged.

4. The name of the instructor(s) in charge, when known at press time.

1.
Civil and Sanitary Engineering

1.01 ***Geotechnical Science***
Prereq.: 5.02, 8.02
Year: U (1) 3–1–5
The basic principles of the earth sciences, selected from the standpoint of their implication to engineered construction projects. Origin and composition of the shallow portion of the earth's crust, with special emphasis on soil and soft rocks; basic principles of clay and rock mineralogy, weathering; geomorphology; heat balance of earth, general circulation of atmosphere and oceans; elements of the hydrologic cycle, with emphasis on precipitation, infiltration, surface and subsurface run-off. *R. V. Whitman*

1.02T ***Human Ecology and Engineering***
Prereq.: 2.403, 5.02, 8.04
Year: U (1) 3–3–3
Engineering problems in the control of land, air, and water resources to fulfill the requirements of man and industry. The interaction of man and his environment. Discussion of human physiology, toxicology, genetics, and disease transmission as they relate to public health and the environmental systems of land, air, and water. Engineering control of disease vectors, highway and industrial accidents. Control of air-borne, water-borne, solid, and radioactive wastes. *G. T. Bryant, Hardy*

1.03 ***Social and Political Factors in Engineering***
Prereq.: 1.04, 21.04
Year: U (2) 3–0–6
Interaction of technical, social, and political factors in policy-making processes. The impingement of social and political forces on engineering decision-making. Introduction to the notion of compromise as contrasted to optimization in the resolution of conflicts. Theory of formal organizations. Theories of decision-making. Case studies of policy-making processes involved in urban redevelopment and transportation planning. *Lang*

1.04 ***Mathematical Methods in Civil Engineering***
Prereq.: 18.04, 18.10
Year: U (2) 3–2–4
Introduction to modern mathematical methods of formulating and solving civil engineering problems. Synthesis of mathematical techniques drawn from such fields as mathematical modeling, numerical analysis, matrix analysis, and operations research. Organization of problems in computation and computer methods of problem solving. Laboratory assignments and instruction involving student use of available computing machines. *C. L. Miller*

1.05 ***Fluid Dynamics***
Prereq.: 2.02, 2.403, 18.04
Year: U (1) 3–2–5
The fundamental principles and methods of fluid dynamics for Newtonian compressible and incompressible fluids. Fluid continua and their properties; conservation of mass, momentum, and energy principles; kinematics; laminar and turbulent motion; energy transfer and energy dissipation; momentum and mass transfer — mixing and diffusion; flow through ducts and porous media; boundary layers, separation, lift, and drag. Laboratory experiments and demonstrations. *Daily*

1.06 ***Particulate Mechanics***
Prereq.: 2.01
Year: U (2) 3–2–5
A study of the principles governing the behavior of assemblages of mineral particles. Consideration of particles ranging from colloids to gravel-size. Treatment of both two-phase (mineral and liquid or gas) and three-phase (mineral, liquid, and gas) systems. Discussion of subjects such as: fluid flow through porous media; interaction of particles; strength and compressibility of multi-phase systems. *Lambe*

1.07 ***Engineering I***
Prereq.: 1.04
Year: U (1) 3–3–3

1.08 ***Engineering II***
Prereq.: 1.07
Year: U (2) 3–3–3
Formulation and solution of engineering problems utilizing the formal approaches of systems engineering and rational design. Applications of probability, statistics, and modern mathematical methods to engineering analysis and design. Experimental approaches to engineering problems, including the design of experiments and the acquisition and analysis of experimental data. Problems drawn from various areas of civil engineering to illustrate the use of analytical and experimental methods. *Holley*

1.11 ***Introduction to Photogrammetry***
Prereq.: 18.04
Year: U (1 or 2) 3–2–4
The metric central projection as a medium for obtaining tridimensional space measurements. Projective geometry, theory of photogrammetric devices, basic control data, photogrammetric control extension, analytical and analog solutions to the photogrammetric problem, and error analysis. Consideration of aerial surveys as applied to civil engineering. *C. L. Miller*

1.12 ***Special Studies in Photogrammetry*** **(A)**
Prereq.: 1.11
Year: G (1 or 2) *Arr.*
Advanced theoretical and applied photogrammetry. Individual and group study of topics arranged by the instructor in charge. Special reading assignments, consultation, and original investigations. Experimental work in Photogrammetry Laboratory. *C. L. Miller*

1.15 ***Computer Approaches to Engineering Problems***
Prereq.: 18.04
Year: U (1 or 2) 2–3–4
Introduction to the application of machine methods to civil engineering problems. Basic concepts of the computer as a problem solving tool of experimental and applied engineering. Approaches to problems in the optimum location and design of civil engineering projects, and discussion of the classes of problems which may be investigated by computer methods. Consideration of selected mathematical techniques appropriate to computer methods. Organization of problems in computation, design, simulation, data processing, and control. Laboratory assignments and instruction involving student use of available computing machines. *C. L. Miller*

1.20 *Transportation Engineering*
Prereq.: 1.04
Year: G (1) 3–0–6
Transportation facilities engineering. Highway traffic analysis, forecasting and assignment, geometric design roadway structure, airport siting, urban transportation. *Bone*

1.211 *Fundamentals of Transportation Systems* (A)
Prereq.: 1.08
Year: G (1) 3–0–6
Physical components of transportation systems. Criteria for evaluating system performance. System characteristics: speed, capacity, energy use, flexibility, and others. Trip characteristics. Cargo characteristics. Cargo conversion. Assembly and distribution systems. Combination of systems. *Lang*

1.212 *Transportation Systems Analysis* (A)
Prereq.: 1.211
Year: G (2) 2–0–4
Mathematical methods for developing models applicable to simulation of traffic flow and to allocation of routes within a network. Evaluation of route segment and system performance. Problems in transportation system analysis and design. *Lang*

1.25 *Route Location* (A)
Prereq.: 1.08
Year: G (2) 2–0–4
Principles of route location for transportation systems, with particular emphasis on highways. Economic principles, environmental considerations, engineering criteria, engineering systems for route selection. *Lang, Wohl*

1.251 *Theory of Traffic Flow* (A)
Prereq.: 18.04
Year: G (1) 3–0–6
Theoretical treatment of the basic characteristics of vehicular flow. Statistical techniques for gathering and analyzing traffic data. Use of analytical probability models for representation of traffic situation. Representation of traffic by symbolic models and evaluation of intersection and network operation efficiency by simulation (Monte Carlo) techniques. *Wohl*

1.252 *Design of Urban Highway Systems* (A)
Prereq.: 1.251
Year: G (2) 2–1–6
Economic analysis of urban highway systems and their components. Principles of maneuver area design. Use of simulation techniques for the optimization of geometric design. Techniques for the planning and programming of large-scale urban traffic systems, including estimation and allocation of traffic demand by mathematical techniques such as gravity model and linear programming. Consideration of functional relationships between highway use and terminal capacity. *Wohl*

1.26 *Ground Facilities for Air Transportation* (A)
Prereq.: 1.08
Year: G (2) 3–0–6
Basic data required for the design of an airport and its terminal, including consideration of future aircraft requirements, air traffic potentials, air traffic control, protection of runway approaches, and influence of aircraft operations on airport environs. Development of airport master plan: runway, taxiway, and apron layouts; paving; drainage and lighting systems. Site planning of terminal area, access roads, parking lots, and loading areas. City-airport transportation. Terminal building layout, passenger and cargo circulation, airline operations, and apron activities. Airport administration and finance. *Bone*

1.27 *Special Studies in Transportation Engineering* (A)
Prereq.: 1.08
Year: G (1 or 2) *Arr.*
Advanced study of a particular phase of highway, railway, or airport engineering, selected with the approval of the instructor. *Staff*

1.282 *Highway and Airport Pavements* (A)
Prereq.: 1.08
Year: G (1) 2–2–4
Characterization of highway and airport traffic loads. Stress-strain distribution in single and multilayer pavements under various loading. Rational and empirical design methods for elastic and viscoelastic layered pavement systems. Materials used and under development for pavement components. Formulating the composition of portland cement, bituminous concrete, and other mixes. Basic steps in construction and control of materials for layered pavement. Laboratory demonstrations and experiments to illustrate principles. *Tons*

1.321 *Soil Behavior* (A)
Prereq.: 1.06 or *1.361*
Year: G (1) 2–3–5
Study of the behavior of both granular and cohesive soils, including the influence on behavior or the crystallographic structure of the soil particles and the chemical composition of the pore fluid. Experimental determinations of soil properties and their dependence on environment. Topics such as: soil composition; permeability; shear strength; and compressibility. *Ladd*

1.35 *Soil Engineering* (A)
Prereq.: 1.361
Year: G (2) 2–3–5
Case studies in soil engineering. Intensive treatment of one or more projects such as earth dam, foundation, retaining wall, or airfield. *R. V. Whitman*

1.361 *Advanced Soil Mechanics* (A)
Prereq.: 1.06
Year: G (1) 3–0–6
An introduction to advanced soil engineering for all graduate students, emphasizing the validity of assumptions common to soil engineering practice. Detailed study of mechanical properties of soils: permeability, capillarity, stress-strain-time characteristics under static and dynamic loading, strength characteristics of cohesionless and cohesive soils; elasticity and plasticity theories applied to soil; subsoil exploration. *Lambe*

1.39 *Special Studies in Soil Engineering* (A)
Prereq.: ——
Year: G (2) *Arr.*
Group discussions of topics of current interest, led by the staff and guest experts. *Ladd*

1.43T *Advanced Materials*
Prereq.: 3.14 or 3.31
Year: U (1) 3–2–4
Cementitious materials based on the lime-silica-alumina phase relationships, portland and other cements, aggregates, concrete design and proportioning, durability, mechanical properties. Engineering materials based on structural clay; other ceramic materials of engineering. Structure of wood and its influence on physical, hygroscopic, and mechanical properties. Destroyers and preservatives. Adhesive bonding. Synthetic polymeric

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materials including plastics and adhesives and their properties based on polymeric structure. Protective coatings. *Dietz*

1.501 *Structural Mechanics*
Prereq.: 2.046
Year: G (1) 3–0–6
Elementary analysis of stress, strain, and deflection of typical structural members. Elastic and plastic behavior of both statically determinate and indeterminate arrangements. Elementary consideration of plates and shells and of buckling and dynamic response of structures. (*Primarily for selected officers of the U.S. Navy and Coast Guard.*) *Norris*

1.502 *Naval Structural Engineering*
Prereq.: 1.501
Year: G (2) 3–1–5
Application of the principles of elementary structural mechanics, and of behavior of materials to analysis and design of typical naval structural arrangements. Development of proper perspective of analysis and design by consideration of simple structural design problems. Laboratory work with models to illustrate behavior of typical structural types. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Mirabelli*

1.503 *Naval Structural Analysis*
Prereq.: 1.502
Year: G (2) 3–1–5
Comprehensive study of methods of structural analysis of two- and three-dimensional frames and frameworks under both elastic and plastic conditions; such as, superposition equations, Castigliano's theorems, slope-deflection, and moment distribution. Brief consideration of stiffness and flexibility matrix methods suitable to use of digital computers. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *R. J. Hansen*

1.511 *Structural Analysis and Design I*
Prereq.: 2.02
Year: U (1) 3–2–5

1.512 *Structural Analysis and Design II*
Prereq.: 1.511
Year: U (2) 3–2–5
Two-term sequence prerequisite for graduate ("A") subjects in structural engineering. Application of the principles of elementary structural mechanics and behavior of materials to analysis and design of typical steel, concrete, and wood structures involved in bridge and building construction. Analysis of elastic and plastic behavior of both statically determinate and statically indeterminate structures considered. Emphasis on beam, truss, and frame structures with a brief consideration of slab, plate, and shell structures. Development of proper perspective of analysis and design by consideration of simple structural design problems. Laboratory work with models to illustrate behavior of typical structural types. *Mirabelli* (*1.511*), *Norris* (*1.512*)

1.521 *Model Laboratory for Structural Design* (A)
Prereq.: 1.512
Year: G (1) 2–3–1
Lectures, conferences, assigned reading, and laboratory work, covering the theory and practice of using models to facilitate the analysis and design of structures and structural elements. Methods and techniques considered for obtaining structural analysis, influence lines, strain and stress distributions, and buckling and vibrational characteristics Use of qualitative and quantitative models to study unusual structural behavior discussed and illustrated by consideration of an actual comprehensive model study. *R. J. Hansen*

1.531 *Special Problems in Structural Engineering* (A)
Prereq.: 1.571, 1.572
Year: G (1 or 2) *Arr.*
Individual study of advanced subjects under staff supervision. Arrangement of each program to suit the particular requirements of the student and interested members of the staff, subject to the approval of the instructor in charge. *Norris*

1.541 *Behavior of Reinforced Concrete Structures* (A)
Prereq.: 1.512
Year: G (1) 3–0–6
Consideration of the actual behavior and strength of various concrete structural members and panels involving a critical comparison of present theory and accepted design procedures with significant experimental and analytical investigations, and with current design specifications. Flexural behavior of reinforced concrete beams including thorough discussion of shear, diagonal tension, and bond; behavior of both short and long columns; buckling of columns, flat and curved panels, and slender flexural members; behavior of shear walls, deep beams, and prestressed members. *Holley*

1.542 *Advanced Reinforced-Concrete and Prestressed-Concrete Design* (A)
Prereq.: 1.541
Year: G (2) 2–0–4
Application of theory and characteristic behaviors discussed in 1.541 to design of civil engineering structures such as slabs, precast decking, rigid frames, arches, prestressed concrete tanks, continuous prestressed concrete girders, etc. *Holley*

1.551 *Advanced Structural Design* (A)
Prereq.: 1.512
Year: G (1) 3–0–6
General principles of structural design. Probabilities of failure or unserviceability. Factor of safety. Ultimate versus elastic design. Stress control and erection of indeterminate structures. Comparison of determinate and indeterminate structures. Economics and preliminary planning of structures. Approximate analysis of beams, trusses, frames, and slabs. Preliminary design of indeterminate structures. *Biggs, Wilbur*

1.552 *Advanced Design of Metal Structures* (A)
Prereq.: 1.512
Year: G (2) 3–0–6
Consideration of behavior and modes of failure of typical metal structures, structural components, and connections as affected by design features, service conditions, and material properties. Comprehensive review of methods of plastic analysis and design of steel structures. Correlation of buckling behavior of structures and structural members with buckling criteria and requirements used in design codes and specifications. Consideration of design techniques to control buckling characteristics. Design to control twisting of structures and structural members. Considerations illustrated by comprehensive design problems involving rigid frames, slender arches, light gage steel structures, tanks and other thin plate constructions, etc. *Mirabelli, Heger*

1.561 *Advanced Structural Mechanics* (A)
Prereq.: 1.512
Year: G (1) 3–0–6
Introduction to the theories of elasticity, plasticity, plates and shells; and to the analysis of buckling of structural members, and of response of structures to dynamic loads. Emphasis on definition of such problems and behaviors; on development of the fundamental relations and principles involved; and on the method of application of these relations to the solution of such problems. More

detailed applications and consideration of typical problems presented in second-term subjects 1.584, 1.586, and 1.588. Prefaced by several weeks devoted to a review and extension of certain important developments from elementary strength of materials. *Norris*

1.571 ***Advanced Structural Analysis*** **(A)**
Prereq.: 1.512
Year: G (1) 3–0–6

1.572 ***Advanced Structural Analysis*** **(A)**
Prereq.: 1.512
Year: G (2) 2–0–4

Comprehensive consideration of methods of structural analysis of both two- and three-dimensional frames and frameworks under linear elastic, nonlinear elastic, and plastic conditions. Prefaced by generalized discussion of stability, determinacy, and indeterminacy of such structures; and by a review of elementary methods of computing deflections and of analyzing indeterminate structures. Among advanced methods considered in detail are superposition equation, Castigliano first and second theorems, complementary energy, slope-deflection, moment distribution, and the generalized relaxation method. Treatment of stiffness and flexibility matrix methods suitable to use of digital computers is integrated with more detailed treatment of such methods in 1.591. Among structures treated in considerable detail are arch structures and suspension systems. *Norris*

1.58 ***Structural Engineering*** **(A)**
Prereq.: 1.512
Year: G (1) 4–0–8

For civil engineering graduate students with a secondary interest in structural engineering. Review of the design of structural members of wood, steel and reinforced concrete; analysis and design of simple and cantilever trusses, three-hinged arches, space frames, gravity dams and retaining walls; computation of deflections; analysis of indeterminate structures by energy methods and moment distribution; approximate analysis of highly indeterminate structures; design of steel and reinforced concrete building frames; ultimate strength design of steel and reinforced concrete structures; design of prestressed concrete beams. *Biggs*

1.584 ***Design of Plate and Shell Structures*** **(A)**
Prereq.: 1.561
Year: G (2) 2–0–4

Application of theory of plates and shells introduced in 1.561 to analysis and design of typical structures: folded plate roofs, cylindrical and spherical shells, conoids, and hyperbolic paraboloids. Design of shells on basis of ultimate strength analysis also considered. *Heger*

1.586 ***Structural Design for Dynamic Effects*** **(A)**
Prereq.: 1.561
Year: G (2) 2–0–4

Analysis of free and forced vibrations, and transient response of structures having many degrees of freedom. Consideration of numerical procedures to evaluate both elastic and plastic response. Development of simplified analysis suitable for design. Bridge vibration, induced vibrations of cables and tall stacks, blast- and earthquake-resistant design among subjects discussed. *Biggs*

1.588 ***Buckling of Structures and Structural Elements*** **(A)**
Prereq.: 1.561
Year: G (2) 2–0–4

Detailed consideration of elastic and plastic buckling behavior of individual column and flexural elements. Buckling of plates considered and applied to local buckling of structural members. Buckling of shells, frames, trusses and arches also discussed. *Biggs*

1.59 ***Structural Engineering Seminar*** **(A)**
Prereq.: 1.571
Year: G (2) 2–0–1

Presentation by students, and occasionally by staff members, of technical papers on topics of current interest followed by group discussion. Requirement for all doctoral candidates majoring in structural engineering prior to taking their general examination. *Norris*

1.591 ***Numerical Methods of Structural Analysis*** **(A)**
Prereq.: 1.512
Year: G (1) 3–0–6

Application of approximate and numerical methods of analysis including relaxation, iteration, perturbation, finite difference, and variational methods to problems in structural analysis covering equilibrium, buckling, and vibration of lumped parameter and continuous systems. Hand and machine methods of computation. Consideration of structural analysis technique especially appropriate for machine computation. *Biggs*

1.612 ***Fluid Mechanics***
Prereq.: 2.02
Year: G (1) 3–0–6

Introduction to theoretical fluid mechanics. Forces on floating and submerged bodies, equations of motion, dynamic similarity, laminar and turbulent flow, skin friction, flow resistance in conduits, cavitation and propulsion, drag, lift, circulation, and principles of turbomachinery. *Eagleson*

1.613 ***Fluid Resistance and Turbulent Diffusion***
Prereq.: ——
Year: U (2) 3–0–6

Fundamental dynamics of real fluids; the physical processes of fluid resistance, turbulent diffusion and mixing common to many fields of technology. Principles of kinetic theory, fluid mechanics, and dynamic similarity applied to turbulent diffusion, mass transfer, and jet mixing. Fluid resistance in laminar and turbulent motion, boundary layer development, separation and secondary flow phenomena. *Harleman*

1.631 ***Advanced Hydromechanics I*** **(A)**
Prereq.: 1.05 or 1.612; 18.05
Year: G (1) 3–0–6

Dynamics and kinematics of nonviscous and viscous fluid motions. General equations of motion, continuity, deformation, rotation and circulation, sources and suites, velocity potential and stream functions, two- and three-dimensional potential flows. Discussion of Navier-Stokes equations, laminar and turbulent flow in ducts, boundary layers. *Daily*

1.632 ***Advanced Hydromechanics II*** **(A)**
Prereq.: 1.631
Year: G (2) 3–0–6

Dynamics and kinematics of fluid motions continued, with applications to structures and fluid machinery. Conformal mapping, vortex motions. Creeping flows and other special laminar flows. Laminar flow stability, generation of turbulence, structure of turbulence in homogeneous and shear flows. Boundary layers in pressure gradients, stall, separation, and secondary flows, boundary layer control. Turbulent mixing, diffusion and transport. Cavitation principles and other two-phase flows. Introduction to non-Newtonian fluid mechanics. *Daily*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

1.65 *Free Surface Flow* (A)
Prereq.: 1.05
Year: G (1) 3–0–6
Steady and unsteady flow in open channels, boundary resistance and boundary layer problems, surface curves, channel transitions and controls, standing waves, hydraulic jump, surges and waves. Secondary flow, stratification, internal currents due to density variation, turbulent diffusion phenomena. *Ippen*

1.66 *Special Problems in Hydromechanics* (A)
Prereq.: 1.632 or 1.65
Year: G (2) *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, and water resources. *Ippen*

1.67 *Seminar in Hydromechanics* (A)
Prereq.: 1.05
Year: G (2) 1–0–2
Recent advances in all fields of hydromechanics; application of developments in related branches of fluid mechanics. Lectures and reports. *Ippen*

1.681 *Experimental Hydromechanics* (A)
Prereq.: 1.05
Year: G (1) 2–0–4
Theory of dynamic similarity, dimensional analysis, and correlation of experimental data. Practical methods of establishing dynamic similarity in models; models of hydraulic structures; shape and roughness effects in distorted models. Movable bed, wave, tidal, salinity, and hydraulic machinery models. Instrumentation and experimental techniques. *Harleman*

1.682 *Experimental Hydromechanics* (A)
Prereq.: 1.681
Year: G (2) 0–8–1
Experimental studies of fundamental phenomena such as turbulence, boundary-layers, surface and form resistance, wave motion, bed-load movement, and density currents. Use of models in hydraulic design exemplified by investigations selected from studies on spillways, bridge piers, river channels, harbor-basins, and hydraulic machinery. *Harleman*

1.683 *Experimental Hydromechanics* (A)
Prereq.: 1.631
Year: G (2) 0–6–0
Abridgment of 1.682, given primarily for naval architects. Experiments on basic flow phenomena involving turbulence, boundary layers, turbulent diffusion, the resistance of submerged bodies, cavitation, and wave characteristics. *Harleman*

1.69 *Water Waves and Sedimentation* (A)
Prereq.: 1.65 or 1.681
Year: G (2) 3–0–6
Hydrodynamics of waves for deep and shallow water, refraction, energy transmission, dissipation, tides and tidal currents, diffusion in estuaries, harbor and breakwater problems. Sediment characteristics, dynamics of fluid-sediment mixtures, entrainment, transport, settling, sedimentation phenomena in streams and coastal waters. *Ippen*

1.71 *Hydrology* (A)
Prereq.: ——
Year: G (1) 3–0–6
Comprehensive treatment of hydrologic theory and practice. Meteorologic principles, climatology, analysis of the hydrologic cycle, statistical analysis of hydrologic data, ground water, unit-hydrograph, storage requirements, flood flows and routing, design storms, rational method of drainage design. *G. T. Bryant*

1.72 *Hydraulic Engineering*
Prereq.: 1.05
Year: G (2) 3–0–6
Application of fluid mechanics to the solution of engineering problems such as the storage in and release of water from surface and subsurface reservoirs, the conveyance of water in natural and artificial open and closed conduits, the dissipation and conversion of flow energies. *Eagleson*

1.731 *Water Power Engineering* (A)
Prereq.: 1.71
Year: G (1) 2–3–4
Application of hydrology and fluid mechanics to design of water power projects. Adaption of general plan to topographic features; use of storage and pondage; introduction of economics in hydraulic design of penstocks, tunnels, surge tanks, and power houses; water hammer; design of penstock anchorages; selection of turbine types; cavitation in turbines. *Staff*

1.732 *Water Resources Development* (A)
Prereq.: 1.71
Year: G (2) 2–3–4
Seminar on engineering and economic problems relating to multiple-purpose utilization of river basins. Advanced developments in design of dams, power plants, and turbines; tidal power, pump-storage plants; relation of water power to thermal power in planning, operation, and economic justification of power systems; cost allocation in multiple-purpose developments. *Staff*

1.801 *Water Treatment Theory* (A)
Prereq.: 1.02T
Year: G (1) 3–3–3
Lectures and laboratory exercises in scientific and engineering principles of unit operations: aeration, coagulation, sedimentation, filtration, demineralization, scale and corrosion, and disinfection control employed in processing municipal and industrial water supplies. *Symons*

1.802 *Sewage and Industrial Waste Treatment Theory* (A)
Prereq.: 1.02T
Year: G (2) 3–3–3
Lectures and laboratory exercises in principles of unit operations and processes of sewage and industrial wastes, including screening, sedimentation, biological coagulation and oxidation by trickling filters and activated sludge, chlorination, anaerobic fermentation, sludge filtration, and drying. Characteristics of industrial waste waters and processes producing them. *Symons*

1.811 *Sanitary Analysis* (A)
Prereq.: 1.02T
Year: G (1) 2–6–4
Chemical principles, analyses, and analytical techniques used in the characterization of water and waste waters and in the control of water purification and waste disposal plants. *McCarty*

1.812 *Sanitary Chemistry* (A)
Prereq.: 1.02T
Year: G (1) 3–0–3
Basic survey of organic chemistry and physical chemistry as related to sanitary engineering phenomena. Emphasis on relationship of structure and reactivity, thermodynamics, colloids and electrochemistry. *McCarty*

1.82 ***Nuclear Waste Disposal*** **(A)**
Prereq.: 1.02T
Year: G (2) 2–2–3
Lectures and laboratory exercises in decontamination of radioactive wastes as related to sanitary engineering. Emphasis on counting techniques, nuclear theory, reactor operations and wastes, and tracer techniques in sanitary engineering research. *G. T. Bryant*

1.83 ***Sanitary Microbiology and Biochemistry*** **(A)**
Prereq.: 1.02T
Year: G (1) 3–3–3
Fundamental aspects of microbiology and biochemistry as related to stream pollution, refuse disposal, water purification, and sewage treatment. Laboratory exercises directed toward basic techniques for field control operations. *Symons*

1.84 ***Public Health Engineering*** **(A)**
Prereq.: 1.02T
Year: G (1) 3–0–3
Epidemiology of communicable diseases and application of engineering principles to the control of the environment and vectors of disease for health of mankind. Biostatics and application of mathematical statistics to laboratory experiments and field surveys in public health. *G. T. Bryant*

1.85 ***Air Pollution Control*** **(A)**
Prereq.: 1.02T, 1.84
Year: G (2) 3–0–3
Causes and effects of atmospheric pollution within industrial plants and communities; engineering principles of cleaning industrial effluents of various types; legislative, economic, and health factors involved in community air pollution control; organization and operation of air pollution control agencies. *First, Hardy*

1.871 ***Special Studies in Sanitary Engineering*** **(A)**
Prereq.: 1.801, 1.811, 1.812, 1.83
Year: G (1) *Arr.*

1.872 ***Special Studies in Sanitary Engineering*** **(A)**
Prereq.: 1.801, 1.811, 1.812, 1.83
Year: G (2) *Arr.*
Advanced studies aimed at coordinating certain theoretical, experimental, and practical phases of sanitary engineering and sanitary science. Problem selection by student with approval of instructor. *Staff*

1.88 ***Sanitary Design*** **(A)**
Prereq.: 1.02T, 1.801, 1.802
Year: G (2) 2–4–2
Application of unit operations and unit processes studied in 1.801 and 1.802 to functional design of treatment plants for water, sewage, and industrial wastes. *McCarty*

1.891 ***Sanitary Engineering Seminar*** **(A)**
Prereq.: 1.02T
Year: G (1) 2–0–4

1.892 ***Sanitary Engineering Seminar*** **(A)**
Prereq.: 1.02T
Year: G (2) 2–0–4
Experience in preparation of oral and written reports; outline of informal reports and formal reports, as well as thesis and technical articles. Oral presentation of thesis studies by each student in sanitary engineering. Examination and evaluation of current sanitary engineering literature; emphasizing wide-spread and interdisciplinary nature of literature and critical appraisal of new research in field. *Staff*

1.921 ***Building Construction***
Prereq.: ——
Year: U (1) 3–0–3
Application of engineering principles to construction methods and practices, especially in building construction field. Consideration of the use of soil mechanics in foundation construction, types of structural systems, structural design of forms for concrete; reinforced concrete, precast concrete, steel, wood, masonry practice applied to building construction; consideration of newer construction methods, materials, and products. Selected field trips. *Heger*

1.931 ***Dwelling House Construction***
Prereq.: ——
Year: U (1) 3–0–3
Conventional and mass production methods for the construction of residential buildings. Assembly of materials, sequence of erection, use of new materials, advanced methods in construction techniques, insulation and condensation problems, planning and field techniques, and modular coordination of building materials and framing details. Relation of mechanical services and equipment to building structure. Selected field trips. Dietz, *Dwelling House Construction.* *Dietz*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

2.
Mechanical Engineering

2.00 *Introduction to Engineering*
Prereq.: ——
Year: 1 (2) 2–0–4
Lectures and demonstrations concerning engineering activities, engineering problems, and representative techniques employed in their solution. Applications of dimensional reasoning and dimensional similitude to the design and interpretation of experiments. Introduction to engineering economics. Properties and applications of engineering materials with particular emphasis upon new developments. Discussion and interpretation of Galileo Galilei's *Two New Sciences*. *Paynter*

2.01 *Mechanics of Solids I*
Prereq.: 8.02, 18.02
Year: U (1, 2) 3–0–5
Introduction to engineering applications of static behavior of rigid and deformable systems. Definition of state of stress and state of strain at a point. Dependence of strain upon stress and temperature. Basic analysis of relations between force balance and geometrically compatible deformation for systems built of rigid, elastic or plastic materials. Applications to stress distributions and deformations in rods, beams, shafts and simple structures. Stability of systems with both rigid and deformable elements. *Cook*

2.02 *Mechanics of Solids II*
Prereq.: 8.02, 18.02
Year: U (1, 2) 3–0–5
Introduction to engineering applications of dynamic behavior of rigid and deformable systems. Kinematics of particles, rigid bodies in translation, rotation and plane motion. Impulse-momentum equations and applications to jets, rockets and gyroscopes. Work-energy equations and applications to both static and dynamic situations. Solution of engineering problems by Lagrange's equation. *Rabinowicz*

2.021 *Dynamic Systems*
Prereq.: 8.02, 18.03
Year: U (2) 3–0–6
Dynamic analysis of linear and quasi-linear physical systems involving the storage and transfer of matter and energy. Speed of response and degree of damping. Dynamically interacting systems. Derivation and solution of linear differential equations. Use of complex numbers in the determination of exponential response, including step and sinusoidal inputs. Block diagram representation of interacting variables, system characteristics, and transfer of matter and energy. Subject developed and taught by interdepartmental staff to include applications to mechanical, electrical, hydraulic, and thermal systems. *Shearer*

2.03 *Dynamics*
Prereq.: 2.02 or 2.021; 18.04
Year: U (1, 2, S) 3–0–6
Introduction to extremum principles in statics and dynamics. Analysis of complex dynamical systems. Rigid body motions in three-dimensional space. Applications to gyroscopic instruments and dynamic response of multi-degree-of-freedom systems. *Crandall*

2.031 *Dynamics*
Prereq.: 2.02 or 2.021; 18.05
Year: U (1, 2) 4–0–8
Theory of extremum principles in static and dynamics and their applications to the analysis of complex mechanical systems. Application of Cartesian tensors to description of spatial motions. Theory of normal modes for multi-degree-of-freedom systems. Applications to gyroscopic instruments and dynamic response of multi-degree-of-freedom systems. *Crandall*

2.046 *Strength of Materials and Dynamics*
Prereq.: ——
Year: G (S) 6–0–8
Elementary analysis of stress and strain in two dimensions; torsion of circular bars; bending of beams; statically indeterminate problems; theories of strength; strain energy; kinematics of particles and rigid bodies; dynamics of particles and rigid bodies in plane motion; work and energy; impulse and momentum. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Dahl*

2.06 *Vibrations*
Prereq.: 2.03 or *2.031*
Year: U (2) 3–0–6
Analysis of vibrations in multi-degree-of-freedom systems. Characterization of physical systems by mathematical models using matrices or partial differential equations. Free vibrations and natural mode theory. Response of such systems to steady-state single-frequency excitation, to transient pulses, and to random vibration. Practical applications to vibration measurement and control. *Crandall*

2.061 *Random Vibration* (A)
Prereq.: 2.03 or 2.031; 18.05
Year: G (1) 3–0–9
Introduction to mathematical description of stochastic processes. Fourier transforms, power spectral density and autocorrelation functions. Analysis of response of mechanical systems to random excitation. Properties of narrow band Gaussian distributions. Application to vibration problems in missiles and jet airplanes involving wide-band random excitation. Fatigue damage under random loading. *Crandall*

2.081 *Strength of Materials*
Prereq.: 2.01
Year: U (1, 2) 3–0–6
Stress and strain in the elastic as well as the plastic states. Failure theories. Elastic and plastic torsion. Thick cylinders and rotating discs. Energy methods. Beams on elastic foundations. Introduction to plates and shells. Limit design. *Dahl*

2.11 *Industrial Plant Engineering*
Prereq.: 2.42
Year: U (2) 3–0–6
Principles of safety engineering and fire protection engineering as applied to the industrial plant before, during, and after construction. Materials and mechanical equipment for heating, ventilating, and air conditioning. Presentation by an authority in each field. *Schwarz*

2.125 *Research in Experimental Stress Analysis* (A)
Prereq.: 2.126
Year: G (1 or 2) *Arr.*
Application of experimental methods to the solution of special problems; current development of theory and technique. *Murray*

2.126 *Experimental Stress Analysis*
Prereq.: 2.081
Year: U (1 or 2) 2–3–4
Common experimental methods of analyzing stress distributions. Photoelasticity, birefringent coatings, brittle lacquers, strain gage techniques and instrumentation, and analogies, as applied to problems involving static, dynamic, and residual stress distributions. *Murray*

2.211 *Advanced Mechanics* (A)
Prereq.: 2.081
Year: G (1) 3–0–9
Stress and strain at a point in three dimensions. Introduction to the theory of elasticity with examples of solutions in two dimensions. Consideration of bending of flat plates; energy methods in elasticity; elastic stability problems. *Den Hartog*

2.212 *Advanced Mechanics* (A)
Prereq.: 2.03 or 2.031 or 2.06
Year: G (2) 3–0–9
The foundations of dynamics leading to Lagrange's equations and Hamilton's principle. Gyroscopic effects in mechanical systems. Analysis of the stability of steady motions. Self-excited vibrations and nonlinear vibrations. *Den Hartog*

2.213 *Gas Turbines* (A)
Prereq.: 2.252, 2.42
Year: G (1) 3–0–9
Application of engineering science to the design and development of gas turbines. Thermodynamics and fluid mechanics for flow phenomena in turbines and compressors. Problems of mechanical strength and vibrations encountered in rotating machinery and blading of turbines and compressors. Design of turbines, compressors, heat exchangers and combustion chambers. Operating characteristics of gas turbine power plants. Consideration of special problems encountered in aircraft applications. *E. S. Taylor*

2.214 *Gas Turbines* (A)
Prereq.: 2.213
Year: G (2) 3–0–9
Detailed study of the design of a gas turbine component. Lectures supplemented by group discussions to solve a specific design problem. Preparation of a report on one phase of the problem by each student. *E. S. Taylor*

2.215 *Methods of Engineering Analysis* (A)
Prereq.: 18.06
Year: G (2) 3–0–9
Study of the nature of complex problems in engineering analysis and of the means of obtaining practical solutions. Formulation of mathematical models for complex physical situations and the organization of computational programs for their solution. Examples chosen from mechanics, hydraulics, heat transfer, elasticity, compressible flow, etc. Numerical methods including iteration, relaxation, finite difference, and variational methods. *Crandall*

2.216 *Plates and Shells* (A)
Prereq.: 2.211
Year: G (2) 3–0–6
Bending stresses and deformation in flat plates of circular and rectangular shapes. Large deflections in plates. General theory of curved thin-walled shell with applications to engineering structures. Plastic behavior of plates and shells. *Dahl*

2.221 *Plasticity* (A)
Prereq.: 2.01
Year: G (2) 3–0–9
Tensor notation for stress, strain and equilibrium and geometrical conditions. Yield criteria and associated flow rule for mono- and polycrystalline material compared to data. Uniqueness. Limit analysis. Plane strain. Applications to deformation, residual stress, and fracture in bars, beams, and tubes. Other current problems. R. Hill, *Mathematical Theory of Plasticity*. *McClintock*

2.222 *Seminar in Plasticity* (A)
Prereq.: 2.221
Year: G (1 or 2) *Arr.*
Further study in branches of plasticity of special interest to the student. Discussion by students of their problems, progress, and results. *McClintock*

2.223 *Dislocation Theory* (A)
Prereq.: 2.01; 2.37 or 3.14
Year: G (1) 3–0–9
Derivation from elastic theory of the properties of dislocations in isotropic and anisotropic materials. Interactions between dislocations and other imperfections. Dislocations in particular crystal structures. Discrete and continuous distributions of dislocations. Applications to theories of yield points, work hardening, creep and fracture. *Siroh*

2.225 *Physics of Strength and Plasticity* (A)
Prereq.: 2.37, 3.14
Year: G (1) 3–0–9
Origin of cohesive forces. Formal stress-strain relationships in elasticity, viscosity, and plasticity. Visco-elasticity and relaxation processes. Physics of elasticity, rubber-elasticity, viscosity, and visco-elasticity. General features of plasticity in crystalline materials. *Orowan*

2.226 *Physics of Strength and Plasticity* (A)
Prereq.: 2.225
Year: G (2) 3–0–9
Dislocation theory of plasticity; yield stress, strain hardening, solution, and age hardening; yield phenomena. Transient and viscous creep. Recrystallization. Structural features and mechanical behavior of polymers. Plastic instability; fracture; brittleness of steels. Fatigue phenomena. *Orowan*

2.228 *Research in Materials* (A)
Prereq.: 2.37
Year: G (1 or 2) *Arr.*
Undergraduate and graduate students carry out experimental or theoretical research work on mechanical properties (strength, plasticity, etc.) of metallic and non-metallic materials. *Orowan*

2.25 *Fluid Mechanics*
Prereq.: 2.02 or 2.021; *2.40* or *2.403;* 18.04
Year: U (1, 2, S) 4–0–8
General introduction to dynamics of fluid motion. Hydrostatics; kinematics; concept of the control volume; continuity equation; momentum theorem; theorem of momentum of momentum; dynamics of inviscid fluid; Bernoulli equations; dimensional analysis; energy equation; viscous and turbulent flow; head losses; fluid meters; fluid machinery; lift; drag; boundary layer; and potential flows. *Erickson*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

2.252 *Gas Dynamics*
Prereq.: 2.25
Year: U (1, 2) 3–0–6
Introduction to gas dynamics. One-dimensional compressible flow, with applications to problems associated with the design of turbojets, ramjets, rockets, combustion chambers, supersonic inlets, supersonic wind tunnels, gas turbines, and steam turbines. Unsteady fluid motions, with applications to problems of water hammer, detonation, and the inlet and exhaust ducts of reciprocating machinery. Two-dimensional and three-dimensional flows at subsonic and supersonic speeds. *Erickson*

2.261 *Lubrication and Friction*
Prereq.: 2.25
Year: U (2) 2–0–4
Presented in two parts: (a) hydrodynamic lubrication covering the Petroff and Sommerfeld equations; criteria for load capacity of bearings; factors for side leakage; and heat balance in a bearing; (b) boundary lubrication covering the effects of lubricant composition, surface finish and bearing materials on bearing performance. *Rightmire*

2.262 *Research in Lubrication* (A)
Prereq.: 2.261
Year: G (1 or 2) *Arr.*
Opportunity for the student to select a research problem (which may be independent of or closely related to the program in progress in the Surface Laboratory), such as lubrication proper, bearing design, surface finish, or fundamental studies of mechanism of friction from experimental and theoretical standpoints. *Rightmire*

2.263 *Lubrication and Friction* (A)
Prereq.: 2.25
Year: G (1) 3–0–6
Derivation of a generalized Reynolds' equation and its application to analysis of sliders, tilting pad bearings, journal bearings, externally pressurized bearings, rolling-contact bearings, dynamic loading; heat balance in bearings; effect of constitution of lubricant, including molecular structure, surface geometry and nature of the bearing surfaces on boundary lubrication; current theories, critical experiments, on dry and boundary friction and their relation to wear. *Rightmire*

2.271 *Fluid Dynamics*
Prereq.: 2.02 or 2.021; *18.05*
Year: U (1) 3–0–6
Broad introduction to concepts, principles, and methods of fluid dynamics. Model and properties of the continuum. Continuity, momentum, and energy equations for the system and the control volume. Kinematics of fluid motion. Equations of motion of nonviscous fluid, and their integration. Theorems of Kelvin, Helmholtz, and Crocco. Potential flows. Navier-Stokes equations for viscous fluids, and applications. Boundary layers, turbulence, and drag. Lift. Dimensional reasoning and similitude. *Erickson*

2.272 *Fluid Dynamics*
Prereq.: 2.271, 2.404, 6.03, *18.06*
Year: U (2) 3–0–6
Topics selected from the following areas: turbomachinery; magnetohydrodynamics; mass, heat, and momentum transfer in boundary layers, jets, and wakes; motion of highly rarefied gases; compressible gas dynamics; unsteady flows, waves, and shocks. *Erickson*

2.28 *Fluid Machinery*
Prereq.: *2.252*
Year: U (1) 3–0–6
Unified treatment from a fundamental point of view of different types of liquid and gas-handling machinery: displacement-type pumps, compressors, and motors; centrifugal and axial pumps and compressors; radial, axial, and mixed-flow turbines; propellers; and jet pumps among topics considered. *Erickson*

2.32 *Non-Metallic Materials*
Prereq.: 2.02 or 2.021; 3.14
Year: U (2) 3–0–6
Chemical, structural, physical, and mechanical properties of polymers, including rubbery materials, glasses, ceramics, textiles, and other non-metallic materials. Production, testing, and engineering use of non-metallic materials. *Orowan*

2.37 *Mechanical Behavior of Materials*
Prereq.: 2.01, 3.14
Year: U (1, 2) 3–2–4
Mechanics of materials in the plastic region; yield conditions, equivalent stress, equivalent strain, review of mechanics of continua for elastic, plastic, Bingham and creeping materials; limit analysis and applications; deformation and fracture of crystalline materials; dislocation theory; wear and friction; brittle fracture and Griffith theory, ductile fracture, transition between fracture modes; creep; fatigue. Deformation and fracture of polymeric materials, survey of stress strain phenomena, chain molecules, rubberlike elasticity, failure mechanisms. Laboratory emphasizing student group projects. *McClintock*

2.39 *Mechanical Behavior of Materials*
Prereq.: 2.01, 3.14, 8.051, 18.05
Year: U (2) 3–2–4
Similar to 2.37, but with more advanced treatment of certain topics. *Argon*

2.40 *Heat Engineering*
Prereq.: 8.02, 18.03
Year: U (1) 3–0–6
First law of thermodynamics. Energy. Properties of liquids, vapors and gases. Second law of thermodynamics. The temperature scale and entropy. Applications to closed systems and to fluids in steady flow, including vapor cycles. *Svenson*

2.401 *Thermodynamics of Fluid Flow*
Prereq.: 8.02, 18.03
Year: U (2) 3–0–6
Laws of thermodynamics with special emphasis on fluid flow applications. Properties of perfect gases. Statistical description of gases and interpretation of thermodynamic properties. Gas kinetic theory and transport phenomena. *J. A. Fay*

2.402 *Thermodynamics*
Prereq.: ——
Year: G (1) 4–0–8
Same as 2.40 with, in addition, studies of mixtures of gases and vapors and applications to heat engine cycles. *(Primarily for selected officers of the U. S. Navy and Coast Guard.)* *Wadleigh*

2.403 *Thermodynamics*
Prereq.: 8.02, 18.03
Year: U (1, 2) 4–0–8
Thermodynamic concepts; the laws of thermodynamics; equilibrium; absolute temperature; entropy and availability; the phase rule; perfect systems; mixtures; flow processes; chemical potential; chemical equilibrium; electric and magnetic phenomena. *Hatsopoulos*

2.404 *Statistical Mechanics and Kinetic Theory*
Prereq.: 2.403
Year: U (1, S) 3–0–6
Classical mechanics of systems of particles and motion in phase space. Quantum mechanical aspects of particle motion. Most probable distribution. Thermodynamic properties of perfect gas and crystal, electron gas, thermal radiation. Elementary kinetic theory using mean free path concept. Transport properties. Boltzmann equation. *J. A. Fay*

2.412 *Heat Engineering*
Prereq.: 2.402, 2.501
Year: G (2) 3–3–6
Applications of fundamental principles of thermodynamics, fluid mechanics, and heat transfer. Design of power and propulsion cycles and processes, and the associated fluid machinery and heat transfer equipment for nuclear and fossil fuels heat sources. Economic and logistic optimization. off-design performance, and control problems of power equipment. Laboratory projects on related topics. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Wadleigh*

2.414 *Engineering Thermodynamics*
Prereq.: 2.403
Year: U (1) 3–0–6
Steady and unsteady heat conduction in solids. Radiation. Convection. Mass transfer. Elementary statistical mechanics. Elementary kinetic theory of gases, distribution function, transport properties. *Hatsopoulos*

2.42 *Heat Engineering*
Prereq.: 2.40
Year: U (2) 3–0–6
Steady-state heat transfer through resistances in series and between flowing streams. Discussion of steam engines, steam turbines and internal combustion engines. Applications of steady flow to gas turbine cycles and refrigerating cycles. Properties of mixtures of air and water vapor and applications to humidity problems. Thermodynamics of chemical reactions. *Svenson*

2.43 *Heat Engineering*
Prereq.: 2.25; 2.40 or 2.403
Year: U (1, 2, S) 3–0–6
Heat transfer: steady-state and unsteady-state conduction; analogies between heat transfer and momentum transfer; convection; correlations of experimental data; radiation; and applications. Mass transfer: molecular diffusion in gases, liquids, and solids; eddy diffusion; analogies; correlations of experimental data; and applications. McAdams, *Heat Transmission;* Eckert and Drake, *Heat and Mass Transfer.* *Rohsenow*

2.451 *Advanced Engineering Thermodynamics* (A)
Prereq.: 2.40 or 2.403; *18.05*
Year: G (1) 3–0–9
Equilibrium; axiomatic thermodynamics; first law, second law and state principles; criteria for equilibrium; absolute temperature, entropy and availability; Maxwell's relations; open systems; the phase rule; systems of one and two components; idealized systems; equations of state; systems involving chemical reactions; thermodynamic potentials; chemical and electrochemical equilibrium. *Hatsopoulos*

2.452 *Advanced Engineering Thermodynamics* (A)
Prereq.: 2.451
Year: G (2) 3–0–9
Continuation of 2.451. Binary mixtures and rectification; the criteria of equilibrium; equilibrium of a pure substance; supersaturated vapor and superheated liquid; chemical equilibrium; solutions of molecular and ionic species. Thermodynamics of irreversible processes; fluxes and forces; phenomenological relations; Onsager reciprocal relation; general analysis of diffusion phenomena; Knudsen flow; electronic phenomena in solids, vacua, and plasmas. Surface phenomena. *Keenan*

2.453 *Advanced Projects in Thermodynamics* (A)
Prereq.: 2.451
Year: G (1) *Arr.*
Selected subjects of current interest in thermodynamics, including the relationship between thermodynamics and other sciences such as mechanics of materials, statistical mechanics, kinetic theory, and quantum theory. No formal lectures; assigned reading or experiment will be arranged on an individual basis in consultation with instructor. *S. C. Collins, Keenan, Rohsenow*

2.454 *Direct Energy Conversion* (A)
Prereq.: 2.404
Year: G (1) 3–0–9
Thermodynamic analysis of direct energy conversion processes. Thermoelectric conversion and thermionic conversion. Principles of quantum statistics, the Boltzmann transport theory, energy band theory of solids, electronic conduction processes, and thermionic emission. Introduction to irreversible thermodynamics and its applications to device operations. Surface phenomena and the theory of cesium converters. Detailed treatment of device characteristics including efficiency, power density, and terminal properties. *Hatsopoulos, Carabateas*

2.46 *Statistical Mechanics* (A)
Prereq.: 2.451 or 5.71
Year: G (2) 3–0–9
Introductory subject for graduate engineering students. Classical mechanics of systems of particles and motion in phase space. Quantum mechanical concepts and energy of microscopic systems. Most probable distribution. Determination of thermodynamic properties of gases, crystals, black body radiation field. Fluctuation theory. Application to plasmas, thermionics, masers, cryogenics. *J. A. Fay*

2.48 *Gas Turbines and Jet Propulsion*
Prereq.: 2.28
Year: U(2) 3–0–6
Analysis and design of gas turbines, rockets, and ram jets. Limitations on performance imposed by thermodynamics, fluid mechanics, and strength. Group design project of gas turbine or jet engine for a particular application. *E. S. Taylor*

2.49 *Advanced Fluid Mechanics* (A)
Prereq.: 2.25, *18.05*
Year: G (1) 3–0–9
Survey of principal concepts and methods of fluid dynamics. Statics. Continuity, momentum, and energy relations for continuous fluids. Kinematics of fluid motion. Governing equations for motion of non-viscous fluid. Vorticity and circulation. Kelvin's theorem. Helmholtz' theorem. Crocco's theorem. Stream function. Potential flow. Conformal transformation. Theory of lift. Navier-Stokes equation for motion of real fluids and applications. Boundary layer theory. Turbulence. Drag. Applications to fluid machinery, propulsion systems, process industries, and aerodynamics. *A. H. Shapiro*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

2.491 *Compressible Fluid Mechanics* (A)
Prereq.: 2.403, 2.49, *18.06*
Year: G (2) 3–0–9
Survey of high-speed gas dynamics. One-dimensional compressible flow, with effects of area change, friction, heat transfer, combustion, gas injection. Supersonic diffusers and wind tunnels. Compression shocks. Method of small perturbations for subsonic and supersonic flow. Method of characteristics for supersonic flow. Hodograph methods. Unsteady wave motion in gases. Experimental methods. *A. H. Shapiro*

2.492 *Advanced Topics in Fluid Mechanics* (A)
Prereq.: 2.49
Year: G (1 or 2) *Arr.*
Selected subjects relating to incompressible and compressible flows, steady and unsteady motion, friction and heat transfer, waves, rarefied gas dynamics, magnetohydrodynamics. No formal lectures; assigned reading and special problems arranged on an individual basis in consultation with instructor. *A. H. Shapiro*

2.493 *Viscous and Turbulent Flows* (A)
Prereq.: 2.491
Year: G (1) 3–0–9
Viscosity; the Navier-Stokes equation, its formulation, its properties, and some exact solutions; boundary layers; turbulence; turbulent boundary layers; boundary layer control; thermal boundary layer; compressible boundary layer; laminar stability and transition to turbulence; separated flows, jets, and wakes; creeping flows at low Reynolds number; drag. *A. H. Shapiro*

2.494 *Dynamics of Rarefied Gas Flows* (A)
Prereq.: 2.49
Year: G (2) 3–0–9
Introduction to the fluid dynamics of gases in the free-molecule and slip regimes, with application to flight at high altitudes and to industrial processes under high vacuum. Concepts of kinetic theory and of molecular models. Boltzmann equation. General transfer equations. Maxwellian distribution of molecular velocities. Isentropic equilibrium flows. Equations of conservation of mass, momentum, and energy for slightly non-equilibrium flows: phenomena of mass diffusion, the Navier-Stokes stress tensor, and heat conduction. The Knudsen number. Momentum and thermal accommodation coefficients. Skin friction, normal pressures, heat transfer, diffusion in free molecule and slip ranges. G. N. Patterson, *Molecular Flow of Gases*. *A. H. Shapiro*

2.495 *Magnetohydrodynamics* (A)
Prereq.: 2.271 or 2.49; 6.03 or 8.72
Year: G (2) 3–0–9
Dynamics of electrically conducting fluids in the presence of electric and magnetic fields. Channel flows, small amplitude wave propagation, shock waves, and boundary layers. Containment and stability of plasmas. *J. A. Fay*

2.496 *Kinetic Theory of Ionized Gases* (A)
Prereq.: 2.271 or 2.49; 6.03 or 8.72
Year: G (1) 3–0–9
Thermodynamic equilibrium of ionized gases. Motion of particles in magnetic and electric fields. The Boltzmann equation and formulation of macroscopic conservation laws. Transport properties. Multiple fluid model of plasmas. Application to magnetohydrodynamic flows. *J. A. Fay*

2.50 *Heat Transfer*
Prereq.: 2.40 or 2.403 or 3.01
Year: U (2) 2–2–4
Steady and unsteady state conduction; natural and forced convection; heat exchangers with steady and intermittent flow; batch heating processes; solidification; radiation from solid surfaces and gases; errors in pyrometry. Laboratory work to supplement lectures. *Rohsenow*

2.501 *Heat Transfer*
Prereq.: ——
Year: G (2) 3–0–3
Fundamentals of conduction, radiation of heat, and the effects of convection, with applications to problems arising in practice. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Rohsenow*

2.521 *Advanced Heat Transfer* (A)
Prereq.: 2.40 or 2.403; *18.05*
Year: G (1) 3–0–9
Review of analogies among heat transfer, friction, mass 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. Radiation from luminous and non-luminous gases. *Rohsenow*

2.522 *Advanced Heat Transfer* (A)
Prereq.: 2.40 or 2.403; *18.05*
Year: G (2) 3–0–9
Steady-state and transient-state conduction problems in heat and mass transfer solved for various constant and fluctuating boundary conditions. Problems in rectangular, cylindrical and spherical coordinates. Thermal stresses resulting from non-uniform temperature distribution. Solution of differential equations by formal mathematics, relaxation method, potential field mapping, method of images, and methods of analogy. *Rohsenow*

2.53 *Heat Measurements*
Prereq.: 2.43 or 2.50 or 2.58
Year: U (1 or 2) *Arr.*
Selected experiments with laboratory investigation of problems connected with the industrial application of heat, such as thermal conductivity, thermal expansion, specific heat, ceramics, etc. *Rohsenow*

2.55 *Power and Propulsion Concepts*
Prereq.: *2.252*, 2.403
Year: U (1) 3–0–6
Application of thermodynamics and fluid dynamics to propulsion, prime movers, and refrigeration devices. Study of gas and two-phase cycles for fossil fuels and nuclear heat sources; piston engine, gas turbine, turbojet, ram jet, and rocket processes and propulsion; refrigeration and liquefaction cycles and processes. *Wadleigh*

2.56 *Power Plant Engineering*
Prereq.: 2.28, *2.43*, 2.55
Year: U (2) 3–0–6
Fossil fuel and nuclear power plants for electric power generation and production of process steam. Design of major components including turbines and steam generation equipment. Auxiliary equipment. Thermodynamic, economic, and operating problems involved in synthesis of the power plant complex. *Ho*

2.57 ***Advanced Conventional and Nuclear Power Plants*** **(A)**
Prereq.: 2.56
Year: G (1) 3–0–9
Design of fossil fuel and nuclear power plants as systems. Performance characteristics of the major plant components; part load performance; control problems. Economic optimization of plant design parameters. *Wadleigh*

2.58 ***Heat Transfer***
Prereq.: 2.25, 2.403, *18.05*
Year: U (1) 3–0–6
Steady-state and transient heat conduction, with and without heat sources in one and two dimensions. Heat transfer in fins and through finned surfaces. Comparison of solutions of heat conduction equations and neutron diffusion equations. Solutions by finite differences and electrical analogy. Heat transfer with free- and forced-convection in laminar and turbulent flow including liquid metals. Heat exchanger design. Boiling. Condensation. Radiation. Mass transfer. *Rohsenow*

2.601 ***Food Engineering***
Prereq.: 8.04
Year: U (1) 2–2–2
2.602 ***Food Engineering***
Prereq.: 2.601
Year: U (2) 2–2–2
Primarily for students in Food Technology. Fundamental principles of thermodynamics with specific application to problems in heat transfer, refrigeration, and air conditioning as related to food processing and preservation. Methods, materials, and equipment used for food processing and preservation. Laboratory work and plant trips to supplement lectures. *Hesselschwerdt*

2.621 ***Refrigeration***
Prereq.: 2.40 or 2.403
Year: U (2) 3–0–6
Discussion of refrigerating cycles. Refrigeration at more than one level. Operation and ratings of various types of compressors, evaporators, condensers, and automatic controls used in commercial refrigerating systems. Heat flow problems in condensers, evaporators, and cooling towers. *Svenson*

2.642 ***Low Temperature Refrigeration*** **(A)**
Prereq.: 2.40 or 2.403
Year: G (1 or 2) 3–3–6
Thermodynamic processes for producing low-temperature refrigeration. Problems of heat exchangers, insulation and rectification. Applications of low-level refrigeration to purification of oxygen and nitrogen. *S. C. Collins*

2.661 ***Heating and Ventilation***
Prereq.: ——
Year: U (1) 2–0–4
Primarily for students in Architecture. Physiological and practical aspects of the problems in producing a comfortable environment. Thermal relationships of the enclosure to climate and weather. Load estimates, insulation, and the techniques of heating, heat generation, and their control. *Hesselschwerdt*

2.662 ***Heating and Ventilation***
Prereq.: 2.661
Year: U (2) 2–0–4
Continuation of 2.661. Air handling equipment, duct systems, and air distribution within the space. Fundamental principles and techniques for cooling and dehumidification for comfort. Equipment and control systems. *Hesselschwerdt*

2.663 ***Air Conditioning***
Prereq.: 2.40 or 2.403
Year: U (1) 3–0–6
For students who have had a basic subject in thermodynamics. Physiological aspects of air conditioning. Air and water vapor mixtures, load estimates for heating, boilers, radiators, and heating systems. Complete and part air conditioning systems, including air handling equipment. *Hesselschwerdt*

2.667 ***Advanced Air Conditioning*** **(A)**
Prereq.: 2.663
Year: G (2) 3–0–9
Psychrometry and its application to problems involving heat and mass transfer in spray equipment. Cooling load estimates and extended surface coils for cooling and dehumidification. Typical air conditioning equipment and control systems will be considered in relation to specific problems. *Hesselschwerdt*

2.671 ***Experimental Engineering***
Prereq.: 2.02 or 2.021; 2.403
Year: U (1, 2, S) 2–4–2*
Engineering laboratory subject for all Mechanical Engineering juniors, extending over two semesters. This subject and 2.672 to play parallel and complementary roles. Major emphasis on interplay between analytical and experimental methods in the solution of research and development problems. A few formal familiarization exercises followed by project investigations of some depth to develop major emphasis in specific case studies. Small student groups supervised by faculty members; facilities of most of the laboratories in Mechanical Engineering Department to be utilized. Lectures to supplement laboratory experience. *Wadleigh*
** Subject carries total credit of 8 units: about 4 to be spent in first term, about 4 in second term.*

2.672 ***Engineering Projects***
Prereq.: 2.671
Year: U (2) 2–0–4
Engineering synthesis and design subject for all Mechanical Engineering seniors. This subject and 2.671T to play parallel and complementary roles. Major emphasis placed upon identification of critical problem areas in comprehensive engineering situations and upon interplay of the many disciplines required to reach acceptable solutions. No formal lectures. Small student groups to work on a few projects with advice of faculty members. Projects drawn from research and development activities and engineering practice of staff. *Dahl*

2.693 ***Refrigeration and Air Conditioning Laboratory***
Prereq.: 2.621, 2.663, 2.671
Year: U (2) 0–3–6
Experimental work involving application and research problems in air conditioning and refrigeration; equipment includes standard condensing units, air washer, heating and cooling coils, constant temperature rooms, and equipment of special design. Facilities available for use of more than one refrigerant. *Hesselschwerdt*

(A) indicates a ubject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

2.721 *Graphical Concepts*
Prereq.: ——
Year: 1 (1, 2) 0–4–2
Graphical methods applied to the formation of concepts and their subsequent analysis. Freehand sketching and drawing as a means of recording and modifying initial ideas, both concrete and abstract, and as a means of analysis and communication. Problems and projects varying from term to term, chosen from various fields: design of mechanisms, optical systems, rocket solid propellants, switching circuits, computer programs, airplane shapes. Topics such as modern geometry, periodic functions, symbolic logic, graphical calculus, and information flow diagrams studied within this graphical framework. *Coons*

2.722 *Descriptive Geometry*
Prereq.: ——
Year: 1 (1, 2) 0–4–2
Representation of three-dimensional space relations by two-dimensional diagrams. Analysis of problems involving points, lines, planes and surfaces into fundamental components. Development of methods of attack and of capacity to think in space terms. Modern problems and project. *D. P. Adams*

2.723 *Elementary Nomography*
Prereq.: ——
Year: 1 (1, 2) 2–0–4
Graphical representation and solution of equations by alignment diagrams based upon plane geometry, including extensive graphical use of central projection, duality of point and line, axis of homology, cross-ratio and other projective tools. Extensive treatment of empirical data. Electrified nomograms as specific-purpose computers. *D. P. Adams*

2.724 *Nomography*
Prereq.: 18.02
Year: U (1, 2) 2–0–4
Nomographic methods for solving equations in three or more variables. Determinant theory, central projections, general projective transformation, corresponding determinant operator. Classical and modern necessary and sufficient conditions for nomographic form. Quasi-alignment diagrams, near-canonical forms, extensive treatment of alignment diagrams for empirical data. Development of the electrified nomogram for function generation and specific-purpose computing. *D. P. Adams*

2.731 *Engineering Design*
Prereq.: 2.02 or 2.021; 2.37; 2.861
Year: U (1, 2) 3–3–6
Instruction and experience in the two main areas of design: creative design and design analysis. Design of a complete and novel machine by each student. Over-all concept and engineering competence equally stressed. Work to be evaluated by visiting experts from industry as well as academic staff members. Lectures devoted to comprehensive case studies in fields of dynamics and strength, kinematics, fluid mechanics, and steady state and transient energy conversion. Objective: illustration of development of rational design criteria through application of fundamentals as well as experimental correlations in complicated systems. Typical of systems studied: small missile power systems, air bearings, cam systems, and statistically stressed shafts. *Mann*

2.732 *Design Concepts*
Prereq.: 2.731
Year: U (1) 2–2–5
The concept-development stage of engineering design, centered around the planning and critical analysis of engineering systems. Case studies, drawn from problems of current and anticipated technological significance, carried out by student groups in cooperation with participating industrial organizations and academic laboratories within the Institute. Such topics as automated production equipment; analog and digital computation techniques in the design and control of engineering systems; data processing and materials handling; and the dynamics, control, and design of transport systems. Objectives: development of ability to plan, organize, and lead engineering projects of broad scope, basing decision on fundamental physical laws, experimental data, experience, and engineering judgment. *Baumann, Richardson*

2.733 *Special Projects in Engineering Design* (A)
Prereq.: 2.731
Year: G (1, 2) *Arr.*
For students desiring to carry on substantial design projects of own choosing. Special lectures and seminars to be arranged when appropriate. Projects arranged on individual basis in consultation with instructor. *Mann*

2.735 *Man-Machine Systems*
Prereq.: 2.03 or 6.05 or 6.053
Year: U (1, 2) 2–2–5
Man as a component in a physical system. Fundamental concepts pertaining to the transmission and processing of information through the human organism. Engineering specification of sensory and motor performance. The human operator in closed loop control systems. Design of displays and controls in the physical environment for most efficient matching to the organism. Laboratory experiments and design practice utilizing a variety of problems in which the man interacts with the machine. *Sheridan*

2.736 *Modern Kinematic Problems*
Prereq.: 2.01, 18.03
Year: U (2) 3–0–6
Comprehensive treatment of displacement, velocity, and acceleration in plane and space motion. Classical and modern higher analytical methods. Chebychef polynomials, matched points and adjustable parameters. Classical geometry for synthesizing generator linkages and coupler-point curves. Modern nomographic synthesis of generator linkages. Modern space-linkage synthesis using complex variables and dual numbers. Computer programming techniques for optimizing modern kinematic problems. *D. P. Adams*

2.751 *Analysis and Design of Engineering Systems I* (A)
Prereq.: 2.03 or 2.031; 2.25; 2.403
Year: G (1, 2) 3–0–9
Application of general system concepts to wide range of physical and engineering processes. Emphasis on variable flow of matter, energy, entropy, and information, directed toward predicting performance for specified designs. Introduction of central theme of functional reticulation into multiported elements. Systematic study of relations and interactions in terms of logical operations, transformations, matrices, ordinary and partial differential equations, signal flow graphs, block and bond diagrams, analogies, and computing systems. Lectures and problem work cover electrical, mechanical, fluid, thermal, chemical, nuclear, and biological systems. *Paynter*

2.752 ***Analysis and Design of Engineering Systems II*** **(A)**
Prereq.: 2.751
Year: G (2) 3–0–9
Continuation of 2.751 with emphasis on the synthesis and design of systems assembled from multiported primitives to accomplish specific tasks and functions. Particular attention given to the use of analog and digital computers as electronic models for studying alternative designs and modes of operation. Lectures and problems dealing with stochastic processes and variables, in both frequency and time domains, and with stationary and nonstationary parameters. Substantial portion of time allotted to original studies on a team basis using available electronic computers. *Paynter*

2.78 ***Hydraulic and Pneumatic Controls***
Prereq.: 2.03 or 2.031; 2.25
Year: U (1) 2–3–4
Theory and design of hydraulic and pneumatic controls and their applications in industry. Problems in the control and measurement of pressure, flow, speed, position, torque, and power. The matching of load to prime power source. Application of basic principles to component and system design. Use of schematic and block diagrams. Introduction to analog computation. Selected laboratory projects. *S. Y. Lee*

2.782 ***Introduction to Automatic Control***
Prereq.: 2.03; 2.25; 6.01 or 6.18; 18.04
Year: U (1, 2) 3–0–6
Introduction to system analysis applied to control systems. Engineers' approach to understanding the unsteady behavior of basic components and processes with emphasis on dynamic response and automatic control. Significance of feedback effects in a wide variety of physical systems. Transient and frequency response applied to solution of system differential equations; criteria of stability; linearization, root locus, analog techniques. Introduction to machine computation. *Shearer*

2.783 ***Advanced Automatic Control*** **(A)**
Prereq.: 2.751 or 2.782 or 6.213 or 16.30
Year: G (2) 3–0–9
General theory of automatic control. Advanced problems in the control of temperature, pressure, flow, speed and position control. Formulation of dynamic relationships for complex systems. Studies of the dynamics of industrial processes and physical systems. Use of analytic techniques in the design of systems for high dynamic performance. Linear and nonlinear systems, lumped and distributed parameter systems. Response to random inputs. Multivariable control. *Shearer*

2.784 ***Instruments for Measurement and Control*** **(A)**
Prereq.: 2.03 or 2.031
Year: G (2) 3–0–6
Presentation of basic concepts and principles important to the design and use of instruments for measuring various physical quantities. Analysis of dynamic behavior of instruments as elements in complex control systems. Detailed presentation of typical examples of digital as well as continuous types of instruments and control system components. Discussion of problems connected with signal amplification, remote indication, transmission and storage. *S. Y. Lee*

2.79 ***Elementary Internal Combustion Engines***
Prereq.: 2.02 or 2.021; 2.40 or 2.403
Year: U (1) 3–0–6
Application of engineering principles to analysis of engine performance. Spark ignition and Diesel cycles. Combustion, friction, cooling, carburetion, and other factors affecting power, efficiency, and general performance. *Rogowski*

2.792 ***Internal Combustion Engines***
Prereq.: 2.55 or 2.79
Year: U (2) 3–0–6
For students interested in research, development, or design in connection with engines and other complex mechanical devices. Review of basic engine theory. Philosophy of design and design procedure. Role of theoretical training, judgment, and experience. Choice of optimum thermodynamic cycle, fuel, cooling, shape, and size to satisfy a given performance specification. Dimensional analysis, engine balance, stress concentration, fatigue, choice of materials. *Rogowski*

2.794 ***Internal Combustion Engine Laboratory***
Prereq.: 2.79 or 2.792
Year: U (2) 0–4–4
Experimental investigation of problems selected from the entire field of internal combustion engines for their educational value and current interest. Application of basic engine theory stressed; experience gained in use of modern methods of measurement and rational analysis of data. Work groups given considerable responsibility for planning and execution of projects. *Rogowski*

2.797 ***Advanced Internal Combustion Engines*** **(A)**
Prereq.: 2.79
Year: G (1) 3–0–9
For students with previous training or experience in this field. Analytical approach to problems of the Diesel engine, gasoline engine, and other types. Fluid flow, thermodynamics, combustion and performance. Taylor and Taylor, *The Internal Combustion Engine*, revised edition, 1960. *Rogowski*

2.798 ***Advanced Internal Combustion Engines*** **(A)**
Prereq.: 2.797
Year: G (2) 3–0–9
Continuation of engine theory. Philosophy of design and design procedure. Choice of optimum design to satisfy a given performance specification. A design study for a particular engine selected by student. *Rogowski*

2.80 ***Automotive Vehicles***
Prereq.: 2.03 or 2.031
Year: U (2) 3–0–6
Analytical approach to vehicle performance, spring suspension, transmission, brakes, etc. Individual study of special problem related to vehicle design. *Rogowski*

2.801 ***Special Problems in Internal Combustion Engines*** **(A)**
Prereq.: 2.48 or 2.79
Year: G (1) *Arr.*
For students with previous training or experience in this subject. Selection of a particular problem by student on which he works independently but under guidance of instructor in field of gas turbines or reciprocating engines or motor vehicles. Work to be summarized in written report. *Rogowski*

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2.821 ***Combustion Gas Dynamics*** **(A)**
Prereq.: 2.25 or 2.271 or 10.30 or 16.02
Year: G (1) 3–0–9
Fundamental treatment of problems in gas dynamics involving simultaneous occurrence of chemical reaction and transfer of heat, mass, and momentum. Combustion thermodynamics. Applied chemical kinetics. Transport coefficients in reacting mixtures. Conservation equations considering chemical reaction and multispecies diffusion. Detonation waves. Propagation of laminar and turbulent flames. Flame stabilization. Diffusion flames. Heterogeneous combustion. Ignition. Combustion in boundary layers. High-temperature gas flow in nozzles and in hypersonic boundary layers. Applications to engineering problems. *Toong*

2.822 ***Advanced Topics in Combustion*** **(A)**
Prereq.: 2.821 or 10.70
Year: G (2) 3–0–9
Selected subjects of current interest in combustion. Comprehensive treatment of combustion principles. Critical examination of theories of ignition, flame propagation, and flame stabilization. Interactions among burning fuel droplets. Combustion instability. Similitude rules. Mechanism of burning of solid propellants. Supersonic combustion. Electric and magnetic effects. *Toong*

2.83 ***Research in Combustion*** **(A)**
Prereq.: 2.821 or 10.70
Year: G (1 or 2) *Arr.*
Selected analytical or experimental problems in combustion, such as flame propagation, flame instability and stabilization, ignition, burning of liquid and solid propellants, stabilization of detonation waves, ablation, electric and magnetic effects, etc. Work arranged on an individual basis in consultation with instructor. *Toong*

2.855 ***Material Removal Processes*** **(A)**
Prereq.: ——
Year: G (1 or 2) 3–0–6
Basic methods of removing unwanted material from engineering structures. New manufacturing methods. Mechanics of the cutting process. Influence of the physical and chemical properties of work and tool materials upon their characteristics. Thermal conditions at the tip of a tool. The friction and wear of sliding tool surfaces and the influence of the surrounding atmosphere. Economic considerations. Application of principles to special selected problems. Introduction to the pertinent engineering literature. *Cook*

2.858 ***Research in the Mechanical Processing of Materials*** **(A)**
Prereq.: ——
Year: G (1 or 2) *Arr.*
Opportunity for the student to work on a special problem of his choice in the general area of mechanical processing, including: material removal, displacement or addition; the alteration of surface properties; or the measurement of processed parts. *Cook*

2.859 ***Manufacturing Technology***
Prereq.: ——
Year: U (2) 3–0–6
Special topics in machine tool design and performance, including: machine tool requirements, kinematic considerations, power supply and transmission, thermal stability, bearings and other components, controls, vibrations and testing of machine tools, automation, statistics, and quality control. New developments including new machining methods, machining of new materials of construction, use of glass and ceramic materials, new fastening materials. *Cook*

2.861 ***Engineering Design and Manufacture***
Prereq.: 2.01
Year: U (1) 4–4–4
Design principles applied to machine elements. Philosophy of design stressing the creative approach to engineering problems. Description and mechanics of manufacturing processes. Determination and application of materials test data to manufacturing process analysis. Application of economic principles to manufacturing. Comprehensive term project to combine manufacturing technology and functional requirements. *Lent, Cook*

2.862 ***Machine Tool Fundamentals***
Prereq.: 2.861
Year: U (2) 2–1–2
Mechanism of chip formation and importance of such items as: tool geometry, physical properties of metal cut, and friction between chip and tool, with regard to tool design and performance. Metallurgical aspects of machining, cutting demonstrations and exercises involving metal cutting dynamometers and thermoelectric apparatus. Application and limitation of current manufacturing processes. Manufacturing economics including selection of equipment. Discussion of industrial organization and personnel problems associated with manufacturing. *P. A. Smith*

2.863 ***Experimental Techniques***
Prereq.: 6.18, 8.04
Year: U (1, 2) 2–1–5
Experimental techniques presented for observation and measurement of fundamental quantities arising in mechanical engineering, such as: displacement, force, time, velocity, acceleration (linear and angular), temperature, roughness, viscosity and wear. Quantities for carrying out these measurements, including the following: electrical (resistance, capacitance, and inductance) mechanical, pneumatic, hydraulic, and optical (including photography). Emphasis on measurement methods employing radioactive tracer technology. Principles analyzed and demonstrated in class and used in laboratory assignments. Discussion of reliability and significance of experimental data; use of statistical methods whenever applicable. *Cook, Rabinowicz*

2.901 ***Principles of Fabric Structure***
Prereq.: 8.01
Year: U (1) 3–0–6

2.902 ***Principles of Fabric Structure***
Prereq.: 2.901
Year: U (2) 3–0–6
Discussion of the properties of fibers as related to the properties of yarns and fabrics; properties of yarns as related to fabrics; construction and finishing of fabrics to produce certain desirable characteristics in these materials. Material dealing with principles of woven fabric structure together with the formation of knitted, braided, twisted, and felted materials. *Schwarz*

2.903 ***Elements of Textile Manufacturing***
Prereq.: 8.01
Year: U (1) 3–0–6
Production and properties of textile raw materials and operations basic to the manufacture of cotton, wool, silk, flax, jute and rayon. *Schwarz*

2.904 ***Principles of Textile Manufacturing***
Prereq.: 2.903
Year: U (2) 3–0–6
Continuation of 2.903 covering the combination of operations such as blending, carding, combing, drafting, twisting, etc., into processes as for cotton, woolen, worsted, spun and thrown filament, and bast fiber materials; includes mill organization studies. *Schwarz*

2.905 *Textile Engineering Analysis* (A)
Prereq.: 2.02 or 2.021
Year: G (1) 3–0–6
Analytical approach to problems of textile materials, textile processes and their interaction. *Fiber rheology:* principles of elasticity, viscoelasticity, creep and relaxation, time-temperature effects, static and dynamic testing. *Textile structures:* differential geometry of twisted yarn, translation of fiber properties into yarn structures, role of fiber variability. *Backer*

2.906 *Textile Engineering Analysis* (A)
Prereq.: 2.905
Year: G (2) 3–0–6
Fiber rheology: molecular structure of fibers, bond strength, dependence of mechanical properties on structure, discussion of X-ray, infrared and electrical measurements. *Textile structure:* cloth geometry, interaction of yarn and fabric structures, mechanical behavior of woven and knitted materials, flow through porous textiles. *Process statistics:* product irregularity, drafting statistics, breakage probabilities. *Process dynamics:* analysis of ring spinning mechanics, balloon dynamics, traveller-ring interaction, spindle vibration, dynamics of weaving. *Backer*

2.907 *Textile Microscopy* (A)
Prereq.: 8.04
Year: G (1) 2–3–2
2.908 *Textile Microscopy* (A)
Prereq.: 2.907
Year: G (2) 2–3–2
Application of optical and microscopical equipment to technical analysis of textiles. Lectures and laboratory on the types of equipment, their use and the technique of textile microanalysis for fiber, yarn and fabric. Opportunity for intensive research on projects involving quantitative determinations; development of technique; application of photomicrography, polarized light, fluorescence, swelling technique, and other processes to textile microscopy. *Schwarz*

2.911 *Textile Research Laboratory* (A)
Prereq.: 2.905, 2.93
Year: G (1) 0–6–2
Introduction to modern instrumentation used in textile research. Emphasis on engineering and statistical planning of experiments, analysis of test mechanisms, interpretation and presentation of results. *Backer, Morgan*

2.912 *Textile Research Laboratory* (A)
Prereq.: 2.906, 2.911
Year: G (2) 0–6–2
Application of the research group method to the solution of textile behavior problems. *Backer, Morgan*

2.913 *Textile Technology Seminar* (A)
Prereq.: 2.905, 2.907
Year: G (1) 2–0–2
2.914 *Textile Technology Seminar* (A)
Prereq.: 2.906, 2.908
Year: G (2) 2–0–2
Students and staff members to present critical discussions of important problems in fiber technology, textile analysis and textile microscopy together with reviews of the current literature, and the results of researches in these fields at the Institute. *Backer, Schwarz*

2.93 *Experiment Planning and Analysis* (A)
Prereq.: 18.03
Year: G (1) 3–0–6
The philosophy and methods underlying the design and interpretation of experiments and the presentation of results. Choice of variables, selection of specimens, size and type of experiment, presentation of data in the form of tables, charts, graphs, and equations, statistical analysis of variable data, comparisons of two or more things subject to interactions, correlation, and the interpretation of quality indices. *Schwarz*

2.951 *Industrial Practice*
Prereq.: ——
Year: U (S) 40 h.p.w.
2.952 *Industrial Practice*
Prereq.: ——
Year: U (1, 2) 40 h.p.w.
Approximately six months of practical work carried out by the Cooperative students in manufacturing, engineering, research, and development at the plants of the organizations which are participating in the Cooperative program. *Murray*

3.
Metallurgy

3.00 *Thermodynamics I*
Prereq.: 5.02, 8.02
Year: U (2) 4–0–6
Essential concepts of thermodynamics and their application to the behavior of metals and materials. The First Law of thermodynamics, thermochemistry, energy balances. Treatment of energies and enthalpies of reaction, transformation and solution. Energy balances of chemical processes. Introduction to the Second Law, entropy and chemical potential. *Elliott, C. M. Adams*

3.01 *Heat and Fluid Flow*
Prereq.: 5.61, 18.04
Year: U (1) 4–3–5
Development of the fundamentals of transport phenomena. Energy and momentum relationships for fluid flow. Study of modes of heat transport in steady-state and transient phenomena. Laboratory experiments illustrating the principles and methods of measurement in fluid and heat transport and providing experience in solution of representative problems. *Elliott*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

3.02 *Chemical Metallurgy*
Prereq.: 3.01
Year: U (1) 4–3–5
Fundamental treatment of important metallurgical processes according to stoichiometric, thermodynamic and kinetic principles. Gas-solid reactions, such as oxidation of metals and roasting of sulphides; reduction of metallic oxides in shaft furnaces and fluid beds. Slag-metal and slag-matte reactions in smelting. Gas-liquid processes such as converting, distillation, and halide reduction. Refining processes such as zone melting and solid phase precipitation; slag and salt-metal refining, vacuum melting, and degassing. Laboratory work to illustrate significant variables in actual processes and to measure thermodynamic quantities in related reactions. *T. B. King*

3.03 *Process Metallurgy* (A)
Prereq.: 3.02
Year: G (2) 3–0–6
Study of integrated metallurgical processes. Application of the fundamental treatment of 3.02 to the extractive metallurgy of the more common metals, such as iron, copper, zinc and aluminum, and of less common metals such as titanium, molybdenum, and chromium.
T. B. King, Ramakrishna

3.09 *Structure of Materials*
Prereq.: ——
Year: 1 (2) 3–0–3
Lectures and demonstrations on selected topics of atomic, molecular, and crystal structure. Correlation of some physical and chemical properties with structure using common engineering materials as examples. *Wulff*

3.10 *Metallurgical Plant Visits*
Prereq.: ——
Year: U (S) 0–3–1
One week of metallurgical plant visits to observe the methods and equipment for the production of iron, steel, and nonferrous metals, as well as metal fabricating processes. Meeting of students and instructor about one week before fall term begins. (*Restricted to students who have completed the third year of Course* III.) *C. M. Adams*

3.12 *Materials Processing*
Prereq.: 3.14 or 3.31
Year: U (2) 3–3–6
Basic principles of shaping and treating metallic, ceramic, and polymeric materials with emphasis on the physical laws underlying those patterns of behavior which cut across many phases of processing. Consideration of economics, innovation, and design of product and operation, as related to choice of process and trends in processing. Application of theory to problems of practice. Relationships of structure, composition, and properties of materials to the making of useful shapes and devices. Complementary to other specific or comprehensive courses in engineering materials and materials science. Laboratory investigations of engineering problems in industrially important processing operations.
C. M. Adams, Backofen, Flemings

3.13 *Foundry Engineering* (A)
Prereq.: 3.14 or 3.31
Year: G (1) 2–0–4
Modern metal casting, theory and practice; including fluid flow, melting and refining, mechanism of solidification, nucleation and grain refinement, heat treatment, metal-refractory reactions, heat flow, etc. Relationships between casting variables, metal structures and cast metal properties. Consideration of specialized casting processes including ingot making, vacuum casting, and zone melting. Economics of the casting process and effect of casting design on quality, structure, and properties of cast metals. Ferrous and nonferrous metals. *Flemings*

3.14 *Engineering Materials*
Prereq.: 8.04
Year: U (1, 2) 4–2–4
Principles underlying the structure, properties, and behavior of materials used in structures and devices. Topics discussed include atomic arrangements and imperfections in crystalline and noncrystalline phases; equilibrium and nonequilibrium phase relationships in one-, two- and three-component systems; kinetics of nucleation, diffusion and phase transformations; elasticity, microplasticity and fracture; corrosion. Correlation of structure with properties in the development of the above subject matter in which metallic, ceramic, and polymeric materials are used. Laboratory work on the common techniques used in the study of structure and measurement of properties. *Wulff*

3.15 *Welding Engineering* (A)
Prereq.: 3.14 or 3.31
Year: G (1) 2–0–4
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 over-all reactions associated with joining. Testing, inspection, and properties of finished joints. Laboratory demonstrations of arc, electron beam, resistance, and other electric welding processes. *C. M. Adams*

3.16 *Powder Metallurgy* (A)
Prereq.: 3.14 or 3.31
Year: G (1) 2–0–4
Principles of surface energy, diffusion, plastic deformation, and fracture applied to the densification of particulate materials. Application of these principles to the processing of refractory metals, carbide tools, and other materials used in electrical, magnetic, and mechanical devices. *Wulff, Brophy*

3.18 *Plastic Working of Metals*
Prereq.: 2.01; 3.14 or 3.31
Year: U (1) 2–0–4
Processing for shape change and property control by plastic deformation and fracturing. Mechanics of deformation from continuum to microstructural levels; elements of slip-line fields and limit analysis; applications of current crystal plasticity theory. Boundary conditions of friction and lubrication in the tool-metal interface. Mechanical behavior under conditions of processing; deformation and fracture at high strain rate and temperature. Microstructure, texture, and properties obtained by working. Apparatus and control; design, economics, and innovation as related to process choice and trends in processing. Examples for discussion from a wide variety of industrial operations. *Backofen*

3.20 *Thermodynamics II*
Prereq.: 5.61
Year: U (2) 4–0–4
Review of the basic laws of thermodynamics. Application of these laws to the analysis of the physical and chemical behavior of metals and other substances. Emphasis on the use of free energy relationships, enthalpies, heat capacities, entropies, activities, etc. in treating phase transformations, chemical equilibria, metallic solutions, and electrochemical phenomena.
Elliott, Ramakrishna

3.21T *Thermodynamics in Metallurgy* (A)
Prereq.: 3.20
Year: G (1) 4–0–6
Advanced treatment of the thermodynamic properties of metallurgical systems. Free energy relations among compounds of the metals. Properties of metallic solutions, substitutional, interstitial, and liquid. Reactions of metals with gases, slags, and refractories. Applications of thermodynamics to problems of metal refining and purification. *Chipman, Ramakrishna*

3.24 *Thermodynamics in Process Metallurgy* (A)
Prereq.: 3.02, 3.21
Year: G (2) 2–0–6
Advanced treatment of the thermodynamic properties of metallurgical systems with emphasis on molten metals, slags, and mattes. Problems in the roasting and reduction of ores. Reactions of molten iron, steel, and other metals with slags and gases, and problems in the refining and solidification of molten metals. *Chipman*

3.25 *Experimental Methods in Metallurgy* (A)
Prereq.: 5.62 or 8.04
Year: G(1) 1–2–0
Special experimental techniques and methods used in metallurgical research, such as: vacuum melting and casting; attainment of extremely high temperatures; special casting methods such as precision casting; vacuum fusion and special chemical analytical techniques; ceramic and refractory evaluation and application; optical and thermocouple temperature reading; temperature control, etc. (*Suggested for all new graduate students in the Department of Metallurgy.*) *Grant*

3.26 *Kinetic Problems in Metallurgy* (A)
Prereq.: 3.20, 3.31
Year: G (2) 2–0–4
Advanced treatment of the rate of metallurgical reactions determined by diffusion in solid and liquid phases, gaseous diffusion, transport processes due to fluid flow, and phase boundary reactions. Illustration of the general principles by reactions involving diffusion of hydrogen, nitrogen, or carbon from a gas phase as donor into solid metals, the oxidation of metals and alloys at elevated temperatures, the reduction of metal oxides and sulfides, roasting processes, and metal-slag reactions. *T. B. King*

3.31 *Materials Science I*
Prereq.: 5.02; 8.04 or 8.041; 18.04
Year: U (1) 4–3–5
Principles underlying the properties and behavior of materials which make them useful in structures, machines, and devices, including atomic arrangements and imperfections in crystalline and noncrystalline phases; equilibrium and nonequilibrium phase relationships in one-, two-, and three-component systems; elasticity, microplasticity, and fracture; recovery, recrystallization, and grain growth; mechanisms and kinetics of diffusion and phase transformations; chemical behavior and corrosion. Introduction of metallic, ionic, and polymeric materials to correlate structure with properties in illustrating the above subjects. Laboratory experiments on some of the basic techniques for revealing the essential nature of real materials. *M. Cohen, D. A. Thomas*

3.32 *Physical Metallurgy*
Prereq.: 3.14 or 3.31
Year: U (2) 3–3–6
Extension of the principles of materials science to the metallic state; nucleation and growth; diffusion-controlled and diffusionless transformations; heat treatment and hardenability; thermal and transformation stresses; relaxation processes; continuous and discontinuous yielding; shear and cleavage fracture; quench aging and strain aging; engineering alloy systems. Laboratory experiments planned and conducted by the students in small groups, providing introduction to research in physical metallurgy; emphasis on report writing, in cooperation with the Department of Humanities.
M. Cohen, D. A. Thomas

3.33 *Applied Physical Metallurgy*
Prereq.: 3.32
Year: U (2) 2–4–4
Factors affecting mechanical, chemical, and physical behavior of materials in service. Property, processing, and economic considerations in materials selection. Laboratory on commercial metals and alloys, with emphasis on microstructures and their interpretation. Classes of alloys; examination of normal and defective materials. *D. A. Thomas*

3.34T *Advanced Physical Metallurgy* (A)
Prereq.: 3.20, 3.32, 3.50
Year: G (1) 4–0–8
3.35T *Advanced Physical Metallurgy* (A)
Prereq.: 3.34T
Year: G (2) 4–0–8
Advanced treatment of important subjects within the general field of physical metallurgy, including application of generalized thermodynamics to metallic systems, thermodynamic aspects of deformation processes, thermodynamics of solid solutions, atomic arrangements in solid solutions, diffusion, nucleation and growth, phase transformations (precipitation, eutectoid decomposition, martensitic reactions, order-disorder transitions), dislocation theory, grain boundary phenomena, recrystallization and grain growth, crystal elasticity and plasticity, anelastic phenomena. The more recent publications covering these topics. *Bever, Averbach*

3.391 *Properties of Metals*
Prereq.: ——
Year: G (1) 3–1–3
3.392 *Properties of Metals*
Prereq.: 3.391
Year: G (2) 3–1–3
Properties of metals with reference to materials used in ship construction. Microstructure, processing, heat treatment, joining and corrosion resistance of nonferrous and ferrous metals. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Hosford (3.391); Floe, Hosford (3.392)*

3.396 *Nuclear Metallurgy*
Prereq.: 3.14 or 3.31 or 3.391
Year: G (1) 2–0–4
Description of physical and nuclear requirements of materials which may be used in reactors. Discussion of metallurgical processes and techniques required to handle these materials, followed by detailed study of uranium, beryllium, graphite, etc. Examination, from a materials viewpoint, of general problems such as heat removal, radiation damage, power generation, breeding. *Ogilvie*

3.42T *Electrochemistry* (A)
Prereq.: 5.62
Year: G (1) 2–0–4
Fundamental principles of electrochemical theory, with illustrations of their applications in practice. Electroanalysis, electroplating, electrowinning of metals, primary and secondary cells, electrophoresis, alkalichlorine production, and related processes. *Uhlig*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

3.43 *Corrosion* (A)
Prereq.: 5.62
Year: G (2) 2–0–4
Theories of corrosion; general principles of corrosion control; selection of metals for use at low and high temperatures. Corrosion testing. *Uhlig*

3.44 *Behavior of Metals at Elevated Temperatures* (A)
Prereq.: 3.32
Year: G (2) 2–0–4
Study of metal and alloy behavior at temperatures at or above the recrystallization temperature (or equi-cohesive temperature). Correlation of alloy preparation variables with the structure and properties of the alloy. Study of the pertinent binary systems prominent in heat resistant alloys. Quantitative evaluation of the present heat resistant alloy field. *Grant*

3.50 *X-ray Metallurgy*
Prereq.: 3.31
Year: U (1) 2–2–4
Use of X-rays in the study of metals. Radiographic examination of metal parts, X-ray diffraction study of the structure and texture of metals. *J. T. Norton*

3.51 *Materials Science II*
Prereq.: 3.14 or 3.31; 8.051
Year: U (2) 4–3–5
Development of a general electronic model of solid materials and examination of the useful physical properties in the light of this model. Classification of solids, electron theory of metals, band theory of solids, theory of alloys, electrical properties of metals, semiconductors and insulators, thermal properties of solids, thermoelectric properties, magnetic properties, dielectric properties, and optical properties. Consideration of metallic, ionic, and covalent crystalline materials, as well as molecular and amorphous substances, in order to demonstrate the basic relationships. Laboratory experiments to illustrate the important phenomena and permit quantitative measurement of some of the basic quantities involved. *J. T. Norton*

3.52 *Advanced Physics of Metals* (A)
Prereq.: 3.50
Year: G (1) 2–0–4
Various problems of the crystalline metallic state and the dependence of physical properties upon structure. Laboratory work in the form of short research problems. *Ogilvie*

3.53T *Advanced X-ray Metallurgy* (A)
Prereq.: 3.50
Year: G (2) 1–3–2
Conferences and laboratory work covering all of the important X-ray diffraction techniques used in the study of metallic structures. *J. T. Norton, Ogilvie*

3.61 *Electric and Magnetic Materials* (A)
Prereq.: 3.31, 8.051
Year: G (2) 2–0–4
Physical basis of the electric and magnetic properties of metals, semiconductors and ceramics. Effects arising from imperfections, impurities, domains, grain boundaries, sub-boundaries. *Averbach*

3.62 *Special Problems in Metallurgy* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Minor investigation in one of the special branches of metallurgy. (*Open only to graduate students properly qualified in the special field.*) *Staff*

3.70 *Ceramics*
Prereq.: 5.02, 8.04
Year: U (1) 2–0–4
Application of chemical and physical principles to the understanding of ceramic processes including slip casting, plastic forming, dry pressing, drying, viscous forming, and pyrochemical reactions. *Cooper*

3.701 *Ceramics Laboratory*
Prereq.: 3.70
Year: U (1) 0–3–0
Laboratory work to accompany 3.70 with commercial processes carried out on a small scale. *Cooper*

3.71 *Ceramics Seminar* (A)
Prereq.: 3.70
Year: G (1) 1–0–2

3.72 *Ceramics Seminar* (A)
Prereq.: 3.70
Year: G (2) 1–0–2
Selected topics in ceramics, varying from year to year, presented by the students and staff; each topic of group interest and followed by group discussion. *Coble*

3.73 *Fundamentals of Ceramic Processes I* (A)
Prereq.: 3.70, 5.62
Year: G (2) 3–0–4
Principles concerned with raw materials, forming, drying, melting, firing and decorating in the ceramic industry. *F. H. Norton*

3.74 *Fundamentals of Ceramic Processes II* (A)
Prereq.: 3.73
Year: G (1) 3–0–4
Application of ceramic principles to manufacture and testing in the fields of glass, whitewares, refractories, abrasives, heavy clay products, and enamels. *F. H. Norton*

3.75 *Special Problems in Ceramics* (A)
Prereq.: 3.70
Year: G (1, 2) *Arr.*
Advanced work in this field. Lectures, conferences, assigned readings, and laboratory work. *F. H. Norton*

3.76 *Physical Ceramics I*
Prereq.: 3.31, 5.61
Year: U (2) 3–0–6
Characteristics of vitreous and crystalline nonmetals. Relationships of atom arrangements and interactions to thermal, mechanical, and electrical properties. Application of phase equilibria, surface properties, atomic mobility, nucleation, and crystal growth to development of structure during fabrication, shaping, heat treatment, and use. Relationship of structures to thermal, electrical, and mechanical properties. *Kingery*

3.77 *Advanced Ceramics Laboratory* (A)
Prereq.: 3.70
Year: G (2) 1–3–2
Fundamentals underlying ceramic processes demonstrated by illustrative experiments. *Cooper*

3.79 *Physical Ceramics II* (A)
Prereq.: 3.70, 3.76
Year: G (1) 3–0–6
Discussion of effects of composition and microstructure on properties. Treatment of various subjects concerned with the thermal, mechanical, and optical properties of ceramic products, including recent publications on these topics. *Kingery*

3.791 *Physical Ceramics III* (A)
Prereq.: 3.79
Year: G (2) 2–0–4
Electrical and magnetic properties of ceramic products as related to composition and microstructure, including recent publications on these topics. *Cable*

3.81 ***Principles of Materials Separation***
Prereq.: 5.61
Year: U (2) 4–3–5
Separation of materials in solid, liquid, or gaseous form according to bulk or surface properties. Movement in fluids, mass transfer, and chemistry of solutions and surfaces. Consideration of physical separations according to size, density, surface characteristics, magnetic, electrical, and kinetic phenomena. Chemical separations include adsorption, solution, precipitation, distillation, segregation, solvent extraction, and electrolysis. Principles applied to representative processes. Laboratory work using real materials and separation techniques. *de Bruyn*

3.82 ***Mineral Engineering***
Prereq.: 3.81
Year: U (1) 3–2–5
Principles discussed in 3.81 applied to problems in mineral engineering. Physical and chemical separation processes such as classification, filtration, flotation, leaching, and ion exchange. Laboratory exercises. *Agar*

3.86 ***Quantitative Mineragraphy* (A)**
Prereq.: 3.81
Year: G (1 or 2) *Arr.*
Advanced subject in mineragraphy in which the quantitative approach is stressed. *Agar*

3.89J ***Physics and Chemistry of Surfaces* (Same subject as 10.61J)**
Prereq.: 5.62
Year: U (1) 3–0–6
Thermodynamic, structural, and kinetic factors underlying surface and interfacial phenomena. Molecular aspects of phase boundaries, intermolecular forces, and origins of surface tension. Capillarity and related phenomena. Thermodynamics of surfaces: surface activity, adsorption, and orientation at interfaces. Spreading, wetting, adhesion, and related processes. Electrical phenomena at interfaces, origins of surface potential, structure of the diffuse double layer, electrocapillarity. Survey of the importance of surface phenomena in processes such as flotation, detergency, corrosion, and catalysis. *de Bruyn, Michaels*

3.90 ***Physical Chemistry of Surfaces* (A)**
Prereq.: 3.20 or 5.71; 5.62
Year: G (1) 4–0–6
Thermodynamics of systems containing extensive surfaces and boundaries. Application to systems with plane and curved interfaces. Surface tensions of solids and liquids. Conditions for three-phase stable contact. The electrochemical double layer at reversible and completely polarizable surfaces. The physical model of the double layer at interfaces, its theory and correlation with thermodynamic surface properties. Electrokinetics, theory, and measurement. Interaction between double layer systems and the stability of suspensions and colloidal solutions. *de Bruyn*

3.901 ***Advanced Mineral Dressing Laboratory* (A)**
Prereq.: 3.81
Year: G (1 or 2) *Arr.*
Study of an ore, a process, or a machine in the field of mineral dressing. *Gaudin*

3.91 ***Materials Separation Processes* (A)**
Prereq.: 3.02, 3.81
Year: G (2) 2–0–4
Critical study of integrated processes of materials separation, particularly in the areas of extractive metallurgy and mineral engineering. Flow sheet design. Economic considerations in process and plant design. *Gaudin*

4.
Architecture and Planning

4.00 ***Structure of the City***
Prereq.: ——
Year: 1 (2) 3–0–3
Lectures, field trips, and readings to familiarize students with their physical environment; to suggest some of the means for its improvement; and to sharpen observation and the sense of design. Greater Boston as an example of urban structure: its historical development, current physical problems, and future possibilities of its industry, commerce, living areas, public institutions, and related services. *Hudnut*

4.011 ***Graphics Laboratory I***
Prereq.: ——
Year: 1 (1) 0–3–2
Freehand drawing exercises to develop accurate observation and skill in graphic representation Linear, light and shadow, detail and perspective renderings of varied subject matter. Control of line, value, color, texture and form using pencil, pen, and brush. *Preusser*

4.012 ***Graphics Laboratory II***
Prereq.: ——
Year: 1 (2) 0–3–2
Continuation of practice in representational techniques. Exercises employing graphic devices useful in all types of freehand drawing. Use of charcoal pencil, pen and ink, and water color as effective means to create the graphic equivalent of what is observed or visualized. *Preusser*

4.02 ***Form and Design***
Prereq.: ——
Year: U (1, 2) 0–9–11
Study of visual and structural form in the areas of design where art, science, and technology are interdependent. Studio and shop experiments on the proportion of spaces, scale, shape, volume, structure, texture, line, plane, or color. Emphasis on imagination, materials, and techniques directed to enlarge the individual's capacity to create an aesthetic form. *Filipowski*

4.031 ***Visual Design Problems***
Prereq.: 21.04
Year: U (1) 2–6–0
Introduction to creative art. Development of imagination and observation. Analysis of visual elements and their organization. Drawing and painting in the studio, supplemented by lectures. *Preusser*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

4.032 ***Visual Design Projects***
Prereq.: 4.031
Year: U (2) 2–6–0
Creative work in painting. Application of visual art principles. Projects encouraging individual expression and inventive use of media. Lectures relating studio work to the role of art in bringing aesthetic order to industrial society. *Preusser*

4.04 ***Light and Color***
Prereq.: 4.02
Year: U (1) 0–9–11
Study of light and color in all aspects relevant to their creative manipulation in art and architecture. Studio work supplementing a survey of the physical, physiological, and psychological phenomena of light and color. Analysis of the historical use of these elements and exploration of new tools and media. *Kepes*

4.06 ***Advanced Visual Design* (A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Studio projects in the visual arts as elements in an architectural setting; visual communication through exhibition design, posters, and architectural use of lettering and signs; visual documentation, or the graphic presentation of environmental situations and ideas. *Kepes*

4.11 ***Architectural Design***[1]
Prereq.: ——
Year: U (1, 2) 0–9–11
Use of small-scale problems of familiar subject matter to establish the basic concepts of architectural order through harmonious relationships between use and form, building and land, structure and space, materials and appearance. Emphasis on acquisition of skill in the conventional methods of representing architectural form with orthographic, perspective, and freehand drawing and by models. *Staff*

4.131 ***Architectural Design***[1]
Prereq.: 4.11
Year: U (1) 0–9–11
4.132 ***Architectural Design***[1]
Prereq.: 4.131
Year: U (2) 0–9–11
A series of projects for simple buildings, to develop, as rapidly as possible, awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available to him for effective satisfaction of the common environmental needs of our culture. Work on separate building units with definitely stated use patterns with ample opportunity for experimental study of appropriate structural systems and search for the uses of building materials most expressive of their physical properties. *Staff*

4.141 ***Architectural Design***[1]
Prereq.: 4.132, 4.32
Year: U (1) 0–12–8
4.142 ***Architectural Design***[1]
Prereq.: 4.141
Year: U (2) 0–12–8
Introduction of problems arising in connection with more complex plan organization, the grouping of buildings, buildings of multistory construction, mass circulation movements, and areas requiring specialized space forms or equipment or having multiple uses. Consideration of the thermal problems of buildings, the distribution of daylight and artificial light, and the control of sound in buildings as they influence the design concepts and also in the material and special installations associated with them. *Staff*

4.151 ***Architectural Design***[1]
Prereq.: 4.142
Year: U (1) 0–12–8
Final term of design with emphasis on the 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. Study of plans for long-range development giving students increasing experience in the analysis of real-life situations requiring program research. *Staff*

4.153 ***Thesis Research***
Prereq.: 4.142
Year: U (1, 2) 0–6–0
Selection of subject and site for undergraduate thesis project and determination of the requirements and conditions to be met in the solution. Independent work under the guidance of the Thesis Committee. *Staff*

4.161 ***Architectural Design* (A)**[1]
Prereq.: 4.151
Year: G (1) 0–15–15
4.162 ***Architectural Design* (A)**[1]
Prereq.: 4.161
Year: G (2) *Arr.*
Concentration of project work on areas of architectural expression which have been most inadequately resolved in contemporary urban life, with the aim of orienting the mature student toward a serious contribution to some of these problems. Exploration of the full implications of the subject under study through organized group research and seminar activity leading to individual and team solutions. *Staff*

4.163 ***Thesis Research* (A)**
Prereq.: 4.161
Year: G (1, 2) 0–6–0
Selection of subject for graduate thesis project and preparation of a program to guide the design phase of the thesis. Independent work under the guidance of the Thesis Committee. *Staff*

4.17 ***Architectural Design, Special Problems***
Prereq.: ——
Year: U (1, 2) *Arr.*
Supplementary work on individual or group basis. Registration subject to prior arrangement for subject matter and supervision by staff. *Staff*

[1] ***A note about the subjects in Architectural Design***
The sequence of undergraduate subjects in Architectural Design provides cumulative experience with a large number of design problems, ranging over the whole field of architectural practice. In general, each problem is presented as a design situation in a complete context; it requires an evaluation of all pertinent factors of site, climate, purpose and social setting, and provides scope for the application of the student's growing knowledge of materials and building techniques, his skill in arranging space, his sense of relative values, and his artistic sensitivity. This learning by doing is reinforced by class discussions, individual and group criticism, and exhibition and evaluation of completed work. Through a combination of collaborative and individual tasks, the student learns the value of cooperative effort as well as the responsibility for independent creative work. While at all times the need for a broad view of all design considerations is stressed, the several successive terms focus in different ways on major areas of emphasis.

4.18T *Collaborative Design* (A)
Prereq.: 4.142 or 4.261
Year: G (1) 0–12–12
Project work on design problems which will benefit from collaboration between architects and city planners or between these groups and other disciplines. *Staff*

4.19 *Special Problems in Architectural Design* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Supplementary design work for graduate students. Registration subject to prior arrangement for subject matter and supervision by staff. *Staff*

4.233 *Representation*
Prereq.: ——
Year: G (1) 0–3–1
Use of graphic techniques to record or control the environment and to express ideas: freehand drawing, elementary drafting, three-dimensional models, surveying and mapping, diagrams, graphic presentation. The common principles underlying these techniques and their use as tools in analysis. For entering planning students without background in design fields. *Lynch*

4.241 *Community Planning Design*
Prereq.: 4.233, 4.53
Year: G (1) 0–12–12
Problems in planning of the physical environment. The functional, social, aesthetic, and economic consequences of physical arrangement at the city scale, in the light of fundamental human objectives. Workshop problems in real situations, but under generous limits of time-scale and capability. *Lynch*

4.261 *City and Regional Planning* (A)
Prereq.: 4.241
Year: G (2) 0–12–12
Practical application of city and regional planning theory to towns, cities, and regions, including problems of replanning, redevelopment, and urban renewal in existing communities. Individual problems, supplemented by group projects worked out in collaboration. Work in field, library, and studio leading to written, oral, and graphic presentations. *Staff*

4.262 *City and Regional Planning* (A)
Prereq.: 4.261
Year: G (1) 0–12–12
Advanced problems in city and regional planning, including pioneering studies and studies in specialized areas. *F. J. Adams*

4.263 *Problems in Urban Design* (A)
Prereq.: 4.18T, 4.261
Year: G (2) 0–12–12
Advanced problems in planning for the visual form of the environment at the scale of cities or regions. *Lynch*

4.30 *Architectural Form and Structure*
Prereq.: ——
Year: U (1) 3–0–6
Qualitative analysis of space frames, including the use of models. Quantitative analysis of statically determinate space frames, including those reducible to planar elements. Continuity in rigid planar frames. Qualitative and quantitative analysis of continuous beams and single-story frames. *Gelotte*

4.31 *Structural Analysis*
Prereq.: 2.01, 4.11
Year: U (1) 2–6–0
Principles of statics and strength of materials applied to the analysis of elementary architectural structures and details of assembly. Consideration of loads in the qualitative analysis of continuous beams and frames. Design and analysis of a simple truss given concurrently with Architectural Design. *Gelotte*

4.32 *Structural Analysis*
Prereq.: 4.131, 4.31
Year: U (2) 2–6–0
Design and analysis of elementary reinforced concrete floor systems, beams, columns, and footings, including a qualitative analysis of continuity in building frames. Building types in steel and reinforced concrete and design and analysis of their principal elements. Application of principles to a problem given concurrently in Architectural Design. *Gelotte*

4.33 *Structures Seminar*
Prereq.: 4.32
Year: U (1) 2–0–4

4.34 *Structures Seminar*
Prereq.: 4.33
Year: U (2) 2–0–4
Comparative analytical study of those properties of structural systems and materials which should find a characteristic and clear formal expression in contemporary architecture. *Weidlinger*

4.41 *Architectural Acoustics*
Prereq.: 8.02
Year: U (1) 3–0–5
Principles of acoustical design for good hearing conditions and control of noise in rooms and buildings; design criteria; analysis of sound absorption and transmission; acoustical properties of room shapes, structures, and surface materials; laboratory demonstrations. *Newman*

4.42 *Special Problems in Architectural Acoustics* (A)
Prereq.: 4.41
Year: G (1 or 2) *Arr.*
Broad study of functional acoustic design in architecture (based on project work in actual buildings where possible), sound distribution and diffusion in rooms, and sound transmission through building structures. Conducted in the Acoustics Laboratory. *Newman*

4.43 *Industrialized House* (A)
Prereq.: 4.142
Year: G (1) 2–2–4
Architectural design of single and multi-family housing, considered in the light of production problems in the industries producing basic materials, prefabricated dwellings, and new site developments. Improvements in design consistent with the conditions imposed by mass production. Seminars, evening discussions, field trips, reading, preparation of papers and sketches. *C. Koch*

4.47 *Site Planning*
Prereq.: ——
Year: G (2) 1–2–3
Arrangement of structures on the land: building grouping, land use and circulation planning, site engineering, landscaping. Lectures and brief exercises in design and field analysis. *Lynch, Myer*

4.51 *Introduction to City and Regional Planning*
Prereq.: ——
Year: G (1) 1–0–2
Objectives and scope of comprehensive physical planning as applied to urban and rural areas. Basic concepts and theories of planning. Examples of comprehensive plans for cities and regions. *F. J. Adams*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

4.52 ***City Planning Principles***
Prereq.: ——
Year: U (2) 2–0–4
Historical background of the modern city planning movement. Evolution of the modern city and relation of architecture and engineering to problems of city development and civic design. Fundamental principles of city and regional planning.

4.53 ***Components of the Urban Environment***
Prereq.: ——
Year: G (1) 3–0–6
Physical nature and characteristics of the urban environment and its component parts. Land uses for residences, commerce, industry, institutions, etc. Circulation elements: streets, expressways, transit, parking. Physical structure and relationship of parts of city and regional development. *J. T. Howard*

4.54 ***City Planning Techniques***
Prereq.: 4.53
Year: G (2) 3–0–6
Survey, analysis, and design methods and practices in comprehensive planning: population and economic development, land use, circulation, other components of the city or metropolitan general plan; relationship of planning to implementation techniques, zoning, urban renewal, etc. *J. T. Howard*

4.55 ***City Planning Administration*** **(A)**
Prereq.: 4.54
Year: G (1) 2–0–4
Methods and practices of planning and implementation; organization of planning agencies, relationships to government and private operations; techniques of administration. *J. T. Howard*

4.56 ***Regional Planning Seminar*** **(A)**
Prereq.: 4.54
Year: G (2) 2–0–4
Critical review of regional, state, and national planning experience in the United States; analysis of principal regional planning problems and investigation into significant current trends in regional planning. *J. Friedmann*

4.571 ***Urban Landscape*** **(A)**
Prereq.: 4.52 or 4.53
Year: G (1) 2–0–4
The city and its components as aesthetic elements. Role of plan organization, spatial relations, symbol, silhouette, scale, view, movement, light, color, sound, detail, etc. Presentation through field observation, group projects, and seminar discussion. *Lynch*

4.572 ***The Visual Plan*** **(A)**
Prereq.: 4.571
Year: G (2) 2–0–6
Techniques of analysis, design, and presentation in preparation of the urban visual plan as a part of the total planning process. Design principles, typical problems, case studies. (*Seminar, limited registration.*) *Lynch*

4.58 ***Theory of City Form*** **(A)**
Prereq.: 4.54
Year: G (2) 2–0–6
Analysis of the functioning, effects, and implications of the general form of the urban physical environment. Effect of this form on basic human objectives. (*Seminar; limited registration. Not offered 1961–62.*) *Lynch, Rodwin*

4.59 ***Theory of the Planning Process*** **(A)**
Prereq.: 4.54
Year: G (2) 2–0–6
Current theories and research in planning, planning organization and action, and the relationship of physical planning to the general theory and process of planning. Required papers and other exercises. (*Registration limited.*) (*Not offered 1961–62.*) *Rodwin, Lynch*

4.60 ***Selected Topics in the History of Art and Architecture*** **(A)**
Prereq.: 4.65, 4.66
Year: G (1, 2) *Arr.*
Special topics in the history of art and architecture, to be varied at the discretion of the instructor. Range of subjects from the work of an individual to the artistic production of an age or the history of a single significant building. *Millon*

4.61 ***Architecture of Cities***
Prereq.: 21.04
Year: U (1) 3–0–5
Cities of the Western World considered as functional and aesthetic patterns. Cities described and interpreted not merely as aggregations of buildings and streets, but as entities which express the changing ideals of our civilization. Cities as works of art which, being shaped by social and technological circumstance, often exhibit the beauty and dignity of a communal artistry. *Hudnut*

4.62 ***Architecture in the Contemporary City***
Prereq.: 21.04
Year: U (2) 2–0–4
Concepts and traditions of architecture as these have been altered in our time by social and technological change. The new architecture considered as a consequence of those industrial revolutions which have also created the new structure of the city. Seminars for advanced students, reviewing the impact on architecture of the factory system and mass production; of political liberalism and the end of aristocratic authority; of population growth, congestion, and the escape to the suburbs; of mechanized transportation and communication; and of the new orientations of thought and feeling which these imply. *Hudnut*

4.65 ***Introduction to Art and Architecture***
Prereq.: 21.04
Year: U (1) 3–0–5
Italian Renaissance period, with comparative study of Ancient, Medieval and Baroque periods. Formal, social, and philosophical studies of art and architecture. Lectures, group conferences, museum visits. *Bush-Brown, Millon*

4.66 ***Modern Art and Architecture***
Prereq.: 21.04
Year: U (2) 3–0–5
Art and architecture as expressions of the period since 1750. Emphasis on problems in the physical environment of industrial society. Lectures, group conferences, museum visits, site trips. *Bush-Brown, Millon*

4.67 ***Theories of Architecture*** **(A)**
Prereq.: 4.65 or 4.66
Year: G (1) *Arr.*
Chief theories of architectural design since the Renaissance. Seminar with trips to sites. *Bush-Brown*

4.68 ***Architectural Criticism*** **(A)**
Prereq.: 4.65 or 4.66
Year: G (2) *Arr.*
Seminar concerned with questions of quality, expression, and utility in contemporary architecture. *Bush-Brown*

4.69 ***History of Urban Form*** **(A)**
Prereq.: 4.65, 4.66
Year: G (1) 3–0–5
First half of semester, lecture; second half, seminar. Principal focus on Boston. Concentration on city as a whole, rather than as a series of town squares, skylines, or water edges. Study of physical growth of cities as an expression of their social development. Special guest lecturers in the areas of economics, politics, immigration, topography, and social history. Student essays in particular topics. (*Limited to twenty students in architecture and city planning.*) (*Alternate years. Not offered 1961–62.*) *Bush-Brown*

4.70 *People in the Urban Environment*
Prereq.: ——
Year: G (1) 2–0–4
Social characteristics of urban and suburban communities; population and sociological problems arising in cities in connection with establishment of residential patterns, land use controls, housing, and basic environmental facilities. *Greeley*

4.71 *Planning Controls* (A)
Prereq.: 4.54
Year: G (1) 3–0–6
Broad review of public and private legal controls over land development; development of modern planning agencies and their tools: the master plan, official map, capital budget, subdivision control, urban redevelopment and renewal, zoning, and eminent domain; legal problems involved in elastic administration of legal controls through planning boards and boards of appeal; study of leading cases indicating problems faced by the courts in balancing private property interests against the general welfare of the community; comparison with planning controls employed in other countries.

4.74 *Methods of Research in City Planning* (A)
Prereq.: 4.53
Year: G (2) 2–0–4
Lectures and seminars on the treatment, organization, and validity of the data encountered by city planners; use and limitations of some linear and nonlinear analyses of activities in the city; applicability of computers, especially to urban inventory and structures; models of flow and congestion in the metropolis; systems controls in the urban economy. *Fleisher*

4.77 *Housing Problems* (A)
Prereq.: 4.53 or 14.01
Year: G (1) 2–0–5
The meaning and scope of housing problems. The market mechanism for producing housing; evaluation of unsolved economic, social, technical, design, administrative, and legislative problems. The changing and broadening perspective of housing policy in the United States and other countries. Work to include extensive readings and a paper. *Rodwin*

4.78 *Housing Seminar* (A)
Prereq.: 4.77
Year: G (2) 3–0–6
Open to a limited number of students who have taken 4.77 or have the equivalent experience or background. Examination of selected housing problems and research topics. Extensive readings and written reports. (*Not offered 1961–62.*) *Abrams*

4.81 *City Structure and Economic Development*
Prereq.: ——
Year: G (1) 2–0–4
Economic, social, and institutional factors which affect the physical environment of the city and region; the structure which results; and some analytical techniques for evaluating urban and regional characteristics and development trends. *Rodwin*

4.82 *Land Economics Seminar* (A)
Prereq.: 4.81
Year: G (2) 2–0–6
Intensive analysis of techniques for regional economic studies and of the historical development of land system and policy in the United States. Two reports by each student dealing with an economic base study, a regional land problem, or the implications for land use of a normative theory of urban organization. *Abrams*

4.84 *Land-Use Problems in Developing Areas* (A)
Prereq.: 4.81
Year: G (2) 2–0–6
The problems of urbanization in developing countries: patterns of urban growth, problems of resource allocation, efficient distribution of activities. Legal and other techniques of general applicability for solving or forestalling these problems. Open to students from a number of fields, such as law, economics, and city and regional planning. Registration limited to 15. Discussion of papers by three to five experts on aspects of these problems. (*Not offered 1961–62.*) *Rodwin*

4.85 *Real Estate Economics*
Prereq.: 14.01
Year: U (1) 2–0–4
Social, political, industrial and economic factors affecting the location, construction, financing and marketing of real estate and buildings — with emphasis on low-cost housing. *Abrams*

4.95 *Thesis Research* (A)
Prereq.: 4.261
Year: G (1) 0–6–0
Selection of thesis subject, definition of method of approach, and preparation of preliminary thesis outline. Independent study, supplemented by frequent individual conferences with staff members. *F. J. Adams*

4.96 *City Planning Research* (A)
Prereq.: ——
Year: G (2) 0–6–0
Selected topics in city and regional planning. Supervised study, with conferences, readings, and reports. No lectures. *Rodwin*

4.97 *Office Practice*
Prereq.: 4.54
Year: G (S) 0–30–0
Work in the office of a planning commission. Problems in design or research having a definite relation to the activities of the planning commission concerned. Supervision at regular intervals by an instructor. *J. T. Howard*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

5.
Chemistry

GENERAL CHEMISTRY
Undergraduate Subjects

5.01 *General Chemistry*
Prereq.: ——
Year: 1 (1) 4–2–5
Fundamental principles of chemistry: gas laws; mass and energy relationships in chemical changes; writing and the use of chemical equations for quantitative calculations; factors affecting the rate and equilibrium of a chemical reaction; correlation of equilibrium conditions through the mass-action law and the electromotive force of voltaic cells; atomic structure, chemical reactivity of elements, and the Periodic Table; chemistry of certain of the elements of groups 1, 2, and 3 of the Periodic Table. Laboratory work largely quantitative in nature and integrated with lectures and recitations. *Stephenson*

5.02 *General Chemistry*
Prereq.: 5.01
Year: 1 (2) 4–2–5
Application of chemical principles to the correlation of the chemical behavior of the common elements; stability of the various oxidation states; chemistry of the ionic species; quantitative application of the principles of equilibrium to chemical reactions; structural chemistry of crystals and of molecules; acid-base systems; introduction to the chemistry of carbon; nuclear reactions. Laboratory work emphasizing chemical properties of the elements in aqueous solution. Use of facts and principles to develop a scheme for the qualitative separation of the elements. Analysis of unknown mixtures.
J. S. Waugh

INORGANIC CHEMISTRY
Undergraduate Subjects

5.03 *Principles of Inorganic Chemistry I*
Prereq.: 5.02, *5.42, 5.61*
Year: U (1) 2–0–4
Presentation of the theoretical principles of chemical bonding and molecular structure, and their application in a survey of the chemistry of all the elements of the periodic system. Emphasis on the lighter nontransition elements. *Seyferth*

5.04 *Principles of Inorganic Chemistry II*
Prereq.: 5.03, 5.62
Year: U (2) 2–0–4
Continuation of 5.03 with emphasis on the heavier elements and the transition elements. (*Must be taken in the term following 5.03.*) *Cotton*

INORGANIC CHEMISTRY
Graduate Subjects

5.065 *Advanced Inorganic Chemistry* (A)
Prereq.: 5.04
Year: G (1) 2–0–4
Extended treatment of special topics of current interest in modern inorganic chemistry, e.g. organometallic compounds, hydrides, fluorine compounds, clathrate compounds, etc.; treatment in terms of modern electronic and structural theory. (*Alternate years. Not offered 1961–62.*) *Seyferth*

5.067 *Topics in Theoretical Inorganic Chemistry* (A)
Prereq.: 5.04
Year: G (1) 2–0–4
Elements of group theory and its application to problems of molecular structure; treatment of vibrational spectra of inorganic compounds; introduction to ligand field theory and its use in the interpretation of spectral and magnetic properties of compounds of the transition elements; other current problems in theoretical inorganic chemistry, as time permits. (*Alternate years.*) *Cotton*

5.09 *Radiochemistry* (A)
Prereq.: 5.62
Year: G (1) 3–0–3
Introduction to nuclear science and chemical aspects of the nuclear energy industry. Chemistry of production, isolation, and identification of radioactive atoms, and techniques of preparation and measurements of radioelements. Applications of radiotracers to chemical problems. *Coryell, Irvine*

5.091 *Radiochemistry Laboratory* (A)
Prereq.: 5.09
Year: G (1) 0–3–2
Laboratory study of special topics including radiochemical analysis, the fission process, and the reactions following nucleogenesis. *Coryell, Irvine*

ANALYTICAL CHEMISTRY
Undergraduate Subjects

5.14 *Analytical Chemistry I*
Prereq.: 5.41
Year: U (2) 3–0–3
Principles of quantitative separations and determinations. Application to the determination of inorganic constituents and organic functional groups. Practice in stoichiometrical calculations. *S. G. Simpson*

5.141 *Analytical Chemistry Laboratory I*
Prereq.: 5.14
Year: U (2) 1–8–0
Application of volumetric and gravimetric methods to the determination of typical inorganic constituents and organic functional groups. An original study of a special analytical problem. Introduction to potentiometry, spectrophotometry, and flame photometry. *S. G. Simpson*

5.142 *Analytical Chemistry Laboratory I*
Prereq.: 5.14
Year: U (2) 1–4–0
Abridgement of 5.141. *S. G. Simpson*

5.16 *Analytical Chemistry II*
Prereq.: 5.14, 5.141, 5.61
Year: U (1) 3–0–3
Instrumental analysis. Theory and application of modern optical and electrical instruments in the solution of chemical problems. Polarography, potentiometry, and conductivity; ultra-violet, visible and infra-red spectrophotometry; colorimetry, turbidimetry, nephelometry, fluorimetry, flame photometry, and automatic instruments. *Hume, Ross*

5.161 *Analytical Chemistry Laboratory II*
Prereq.: 5.16
Year: U (1) 1–4–2
Laboratory coordinated with the topics in 5.16. *Ross*

ANALYTICAL CHEMISTRY
Graduate Subjects

5.192 ***Advanced Analytical Chemistry I*** **(A)**
Prereq.: 5.14
Year: G (2) 2–0–4
Separation methods, including chromatography. Theory and application of separations based upon partition between two phases or upon differences in rates: volatilization and condensation, solvent extraction, precipitation, ion exchange, diffusion. (*Alternate years. Not offered 1961–62.*)

5.193 ***Advanced Analytical Chemistry II*** **(A)**
Prereq.: 5.14
Year: G (1) 2–0–4
Analytical chemistry of the less familiar elements. Problems met in analysis of technical products. Correlation of analytical methods. (*Alternate years. Not offered 1961–62.*)
S. G. Simpson

5.194 ***Advanced Analytical Chemistry III*** **(A)**
Prereq.: 5.14
Year: G (2) 2–0–4
Application of statistical methods to analytical problems with emphasis upon significance testing, control chart methods, analysis of variance, fitting of equations to experimental data and the design of experiments. (*Alternate years.*)
Hume

5.196 ***Advanced Analytical Chemistry IV*** **(A)**
Prereq.: 5.14
Year: G (1) 2–0–4
Quantitative organic analysis by chemical and physical methods with emphasis on determination of functional groups and application of ultraviolet, visible and infrared spectroscopy, mass spectrometry, etc. (*Alternate years.*)
Biemann

ORGANIC CHEMISTRY
Undergraduate Subjects

5.41 ***Organic Chemistry I***
Prereq.: 5.02, 8.02
Year: U (1) 4–0–4
Introduction to the chemistry of carbon compounds. Survey of the principal classes of aliphatic and aromatic compounds and their reactions.
Swain

5.412 ***Organic Preparations I***
Prereq.: 5.02, *5.41*
Year: U (1) 1–4–0
Application of the techniques of synthetic organic chemistry to the preparation and purification of simple organic compounds.
W. R. Moore, Ashdown

5.416 ***Organic Preparations I***
Prereq.: 5.41
Year: U (1) 1–5–0
Preparation and purification of a series of simple organic compounds by typical reactions illustrating the synthetic techniques of organic chemistry.
Berchtold, Ashdown

5.42 ***Organic Chemistry II***
Prereq.: 5.41
Year: U (2) 4–0–4
Continuation of 5.41. Study of organic reactions, with emphasis on the relation between structure and reactivity.
Büchi

5.422 ***Organic Preparations II***
Prereq.: 5.412, *5.42*
Year: U (2) 1–4–2
Introduction to the literature of organic chemistry. Study of advanced preparations involving special techniques. (*Only for those intending to mjaor in chemistry.*)
W. R. Moore, Ashdown

5.426 ***Qualitative Organic Analysis***
Prereq.: 5.416
Year: U (2) 1–5–0
Identification and separation of mixtures of organic compounds by chemical and physical means.
Berchtold, Ashdown

5.428 ***Qualitative Organic Analysis***
Prereq.: 5.42, 5.422
Year: U (1) 2–7–1
Identification of organic compounds, including current research techniques used for the determination of the structure of organic molecules.
House

5.43 ***Organic Chemistry III***
Prereq.: 5.42
Year: U (1) 2–0–4
Introduction to the theoretical interpretation of reactivity, reaction mechanisms and molecular structure of organic compounds. Application of theories of electronic structure, steric hindrance, and stereochemistry to ionic and free radical reactions, with emphasis on recent developments.
F. D. Greene

5.44 ***Organic Chemistry IV***
Prereq.: 5.42
Year: U (2) 2–0–4
Discussion and evaluation of general synthetic methods of organic chemistry; emphasis on isolation, characterization, and synthesis of products of biological significance (antibiotics, peptides, steroids, and alkaloids).
Berchtold

ORGANIC CHEMISTRY
Graduate Subjects

5.51 ***Advanced Organic Chemistry: Synthesis*** **(A)**
Prereq.: 5.44
Year: G (1) 2–0–4
Organic reactions and the methods by which they are applied to synthetic problems in organic chemistry.
House

5.54 ***Physical Organic Chemistry*** **(A)**
Prereq.: 5.43
Year: G (2) 2–0–4
Mechanism 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.
Swain

5.55 ***Organic Chemistry: Natural Products*** **(A)**
Prereq.: 5.44
Year: G (1) 2–0–4
The chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis. (*Not offered 1961–62.*)
Büchi

PHYSICAL CHEMISTRY
Undergraduate Subjects

5.60 ***Physical Chemistry***
Prereq.: 5.02, 8.02, *18.03*
Year: U (1) 3–0–6
Physical states of matter; first and second laws of thermodynamics; properties of gases and elementary kinetic theory; properties of solutions; electrolytic conduction.
Garland

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

5.61 *Physical Chemistry I*
Prereq.: 5.02, 8.03, 18.03
Year: U (1) 4–0–4
Properties of gases and elementary kinetic theory; first and second laws of thermodynamics; properties of solutions; phase equilibrium; chemical equilibrium and the third law of thermodynamics. *Amdur*

5.611 *Physical Chemistry Laboratory I*
Prereq.: 5.61
Year: U (1) 0–4–2
Coordinated with topics of 5.61.
D. P. Shoemaker, Garland, Hammes

5.613 *Physical Chemistry Laboratory I*
Prereq.: 5.61
Year: U (1) 0–6–3
Coordinated with topics of 5.61. *Garland, Hammes*

5.62 *Physical Chemistry II*
Prereq.: 5.61
Year: U (2) 4–0–4
Continuation of 5.61. Electrolytic conduction, ionic equilibria, and voltaic cells; introduction to molecular structure; elementary statistical thermodynamics; rates of chemical reactions. *Lord*

5.621 *Physical Chemistry Laboratory II*
Prereq.: 5.611, *5.62*
Year: U (2) 0–4–2
Coordinated with topics of 5.62. *Garland, Hammes*

5.623 *Physical Chemistry Laboratory II*
Prereq.: 5.613, *5.62*
Year: U (2) 0–6–3
Coordinated with topics of 5.62. *Garland, Hammes*

5.64 *Structural Chemistry*
Prereq.: 5.02; 8.05 or 8.051
Year: U (2) 3–0–5
Structure and bonding in molecules and crystals. Introduction to crystallography; nature of ionic, covalent, and metallic bonds; molecular and crystalline structure determination; relation of structure to chemical, mechanical, electrical, and magnetic properties. *D. P. Shoemaker*

5.67 *Introduction to Atomic and Molecular Structure*
Prereq.: 5.62
Year: U (1) 2–0–4
Use of spectroscopic methods to determine the structure of atoms and molecules; elementary theory of atomic spectra; atomic structure and the Periodic Table; theory of molecular spectra. Technique of chemical spectroscopy; analysis of chemical elements by emission spectra; use of infrared and Raman spectra in chemical analysis and in determination of the structure of organic compounds; ultraviolet absorption of molecules and their electronic structure. *Lord*

5.68 *Kinetics of Chemical Reactions*
Prereq.: 5.62
Year: U (2) 2–0–4
The kinetic theory of gases with emphasis on the calculation of collision frequencies, and consideration of theoretical and experimental aspects of the kinetics of homogeneous and heterogeneous reactions in gaseous and liquid systems. *Amdur*

PHYSICAL CHEMISTRY
Graduate Subjects

5.70 *Introduction to Statistical Thermodynamics* (A)
Prereq.: 5.62
Year: G (1) 2–0–4
Elementary statistical mechanics, with applications to simple physical and chemical systems. *J. S. Waugh*

5.71 *Chemical Thermodynamics I* (A)
Prereq.: 5.62
Year: G (1) 2–0–4
Fundamental definitions and concepts; first and second laws of thermodynamics with applications to chemical systems, ideal and real gases, ideal and real solutions; partial molar quantities, chemical equilibrium; third law of thermodynamics and applications to chemical systems; free energy calculations. *Beattie*

5.72 *Chemical Thermodynamics II* (A)
Prereq.: 5.71, *18.05*
Year: G (2) 3–0–6
Development of the general thermodynamic theory from the first and second laws. Application of the theory to homogeneous and heterogeneous systems in which chemical reactions may take place. (*Not offered 1961–62.*)
Beattie

5.73 *Theory of Liquids and Solutions* (A)
Prereq.: 5.70, 5.71, *18.05*
Year: G (1) 3–0–6
Selected topics in the theory of liquids and liquid solutions, including macromolecules and electrolytes. Phenomenological and molecular theories of equilibrium and transport properties. (*Alternate years. Not offered 1961–62.*)

5.74 *Molecular Quantum Mechanics* (A)
Prereq.: 5.75, *18.06*
Year: G (2) 3–0–6
Perturbation theory, variation method. Symmetry properties of wave functions. Theory of many-electron atoms and the self-consistent field; the central field approximation, Russell-Saunders coupling. One-electron theories of molecular binding, molecular orbital and valence bond theories. Hybridization, approximate methods for molecules, special topics. *Thorson*

5.75 *Introductory Wave Mechanics* (A)
Prereq.: 5.62, 8.04
Year: G (1) 2–0–4
Mathematical treatment of wave trains and wave packets; applications of the Schroedinger wave equation to simple and atomic and molecular systems, including use of the operator algebra; the variation method, with application to the hydrogen molecule ion. *L. Harris*

5.76 *Molecular Spectra and Molecular Structure* (A)
Prereq.: 5.75, 18.05
Year: G (2) 3–0–6
Rotational, vibrational and electronic spectra of molecules; use of spectra to find dissociation energies, force constants, inter-atomic distances, molecular symmetry and related quantities; other techniques for study of molecular structure such as dipole moments, magnetic susceptibilities, and nuclear magnetic resonance. (*Alternate years. Not offered 1961–62.*) *Lord*

5.77 *Crystal Structure and the Chemical Bond* (A)
Prereq.: 5.75
Year: G (1) 3–0–6
Application of X-ray, electron and neutron diffraction to the determination of the structures of molecules and crystals. Interpretation of structural results in terms of modern theories of chemical binding. (*Alternate years.*)
D. P. Shoemaker

5.78 *Statistical Mechanics* (A)
Prereq.: 5.70, 5.71, 5.75, 18.05
Year: G (2) 3–0–6
Introduction to the principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, cooperative phenomena, molecular distribution functions, and other selected topics, with applications to gases, liquids and solids. *Garland*

5.79 *Kinetic Theory* (A)
Prereq.: 5.71, 18.05
Year: G (1) 3–0–6
Fundamental concepts of the kinetic theory of gases. Properties of gases at low densities; transport phenomena in relation to molecular interactions; introduction to fluctuations and Brownian motion. *Amdur*

5.81 *Magnetic Resonance* (A)
Prereq.: 5.75, 18.06
Year: G (1) 3–0–6
Interaction of nuclear and atomic moments with radiation and with their surroundings; steady-state and transient nuclear magnetic, paramagnetic, and pure quadrupole resonance experiments; theory of spectra and relaxation times. Emphasis on applications to studies of molecules and crystals. *J. S. Waugh*

RESEARCH

5.90 *Special Problems in Chemistry* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Directed research and study of special chemical problems. *For graduate students only.* *Hume*

5.913 *Seminar in Organic Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.914 *Seminar in Organic Chemistry* (A)
Prereq.: 5.913
Year: G (2) 1–0–2
Discussion of current journal publications in organic chemistry by graduate students and staff members. *Cope*

5.915 *Seminar in Analytical Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.916 *Seminar in Analytical Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of topics of current interest in analytical chemistry by graduate students and staff members.
Biemann (5.915), Ross (5.916)

5.931 *Seminar in Physical Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.932 *Seminar in Physical Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of topics of current interest in physical chemistry by staff members and students. *Hammes*

5.941 *Seminar in Inorganic and Nuclear Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.942 *Seminar in Inorganic and Nuclear Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of current research in inorganic and nuclear chemistry by graduate students and staff.
Seyferth (5.941), Coryell (5.942)

5.951 *Research Conference in Analytical Chemistry* (A)
Prereq.: ——
Year: G (1) 1–0–2

5.952 *Research Conference in Analytical Chemistry* (A)
Prereq.: ——
Year: G (2) 1–0–2
Discussion of research problems under investigation by graduate students and staff. *Ross (5.951), Biemann (5.952)*

5.97 *Research* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Research for any of the advanced degrees in inorganic, analytical, organic, or physical chemistry. *Staff*

6.
Electrical Engineering

6.01 *Introductory Circuit Theory I*
Prereq.: 8.031, 18.03
Year: U (1, 2) 4–0–8

6.013 *Introductory Electric Circuit Theory*
Prereq.: 8.031, 18.03
Year: U (1) 4–0–8

6.02 *Introductory Circuit Theory II*
Prereq.: 6.01
Year: U (2) 4–0–8

6.023T *Electronic Devices and Circuits*
Prereq.: 6.013
Year: U (2) 4–0–8
Two-term sequence for students majoring in electrical engineering. Kirchhoff's laws, network equilibrium equations, algebraic and graphical solutions for resistive circuits; superposition, duality, reciprocity, Thevenin's theorem. Differential equations for linear circuits with exponential excitations; transient and steady-state behavior. Response of circuits to impulses and other singularity functions. System functions as functions of applied and natural frequencies and their geometrical interpretation in the complex frequency plane. Energy relations in simple circuits, etc. Analysis of circuits containing simple nonlinearities, with emphasis on graphical and piecewise-linear methods. Control valves such as transistors and triodes and their description by circuit models. Power amplification by means of control valves, nonlinear energy storage elements, and negative resistance. Circuits exhibiting negative resistance and their role in oscillators. Examples of useful electronic circuits for linear and nonlinear processing of signals. One section of 6.01 and one section of 6.02 conducted in French during 1961–62. *Bose, Stevens (6.01); Wozencraft (6.013); Susskind (6.02); Huffman (6.023T).*

6.03T *Electromagnetic Fields and Energy*
Prereq.: 6.02, 8.041, *18.05*
Year: U (1, 2, S) 4–0–8

6.033T *Electromagnetic Fields and Energy*
Prereq.: 6.023T, 8.041, *18.05*
Year: U (1) 4–0–8
Basic subject for undergraduates majoring in electrical engineering. Treatment of electromagnetism based on Maxwell's equations and built upon the work in second-year physics. Static and quasi-static fields; energy, power flow, and impedance; the field theory of circuit components. Transverse electromagnetic waves in steady state. *Haus (6.03T), Miles (6.033T)*

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6.05 ***Electronic Circuits and Signals***
Prereq.: 6.02, 18.05
Year: U (1, 2, S) 4–0–8

6.053T ***Electronic Circuits and Signals***
Prereq.: 6.023T, 18.05
Year: U (2) 4–0–8

Basic subject for students majoring in electrical engineering. Fourier representation of signals. Modulation, amplification and generation of electrical signals. Limitations on signal transmission imposed by inherent energy storage, noise, and saturation in electronic systems. *Siebert*

6.06 ***Electromechanical Energy Conversion***
Prereq.: 6.03, 18.05
Year: U (1, S) 4–3–5

Required subject for electrical engineering students. Lumped parameter electromechanics. Analytical mechanics and state function concepts in electromechanics; mathematical techniques for analyzing the dynamics of electromechanical energy converters as individual devices and when interconnected into systems. Analysis of dynamic behavior of rotating machines using a generalized model. *Woodson*

6.06T ***Fields, Forces, and Motion***
Prereq.: 6.02, 6.03T
Year: U (1, 2, S) 3–0–6

6.063T ***Fields, Forces, and Motion***
Prereq.: 6.023T, 6.033T
Year: U (2) 3–0–6

Required subject for electrical engineering students. Electromagnetic fields in the presence of moving material bodies, power flow, and energy conversion. General properties of lumped-parameter electromechanical models. Field theory of electromechanical systems containing rigid and eleatic bodies and incompressible and compressible fluids. Hydromagnetic waves and their interaction with fields. *Woodson*

6.061 ***Electromechanical Energy Conversion***
Prereq.: 6.03, 18.05
Year: U (2, S) 4–0–4

Classroom part of 6.06. *Woodson*

6.062 ***Electromechanical Energy Conversion Laboratory***
Prereq.: 6.061
Year: U (2, S) 0–3–1

Experimental aspects of 6.06. *Woodson*

6.063T *See above, following 6.06T.*

6.07 ***Energy Transmission and Radiation***
Prereq.: 6.03, 18.05
Year: U (1, 2) 3–3–6

6.073 ***Energy Transmission and Radiation***
Prereq.: 6.03, 18.05
Year: U (1), 3–3–6

Basic subject for students majoring in electrical engineering. Elementary characteristics of oscillations and waves in one-, two-, and three-space dimensions, with reference to transmission and radiation problems in electrical engineering. Emphasis on steady-state and transient wave motion on transmission lines; resonance interpreted in terms of spatial field configurations and energy, and in time and frequency domains; uniform plane waves; radiation and reception by means of dipole antennas. *Kyhl (6.07), Adler (6.073)*

6.07T ***Energy Transmission and Radiation***
Prereq.: 6.03T, 18.05
Year: U (1, 2) 3–0–6

6.073T ***Energy Transmission and Radiation***
Prereq.: 6.033T, 18.05
Year: U (1, 2) 3–0–6

Basic subject for students majoring in electrical engineering. Elementary characteristics of oscillations and waves in one-, two-, and three-space dimensions, with reference to transmission and radiation problems in electrical engineering. Emphasis on steady-state and transient wave motion on transmission lines; resonance interpreted in terms of spatial field configurations and energy, and in time and frequency domains; uniform plane waves; radiation and reception by means of dipole antennas. *(Not offered 1961–62.)*
Kyhl (6.07T), Adler (6.073T)

6.071 ***Energy Transmission and Radiation***
Prereq.: 6.03, 18.05
Year: U (1) 3–0–6

Classroom part of 6.07. *Kyhl*

6.072 ***Energy Transmission and Radiation Laboratory***
Prereq.: 6.071
Year: U (2) 0–3–0

Experimental aspects of 6.07. *Kyhl*

6.073 *See above, following 6.07.*

6.073T *See above, following 6.07T.*

6.08 ***Molecular Engineering***
Prereq.: 8.051
Year: U (1, 2) 4–3–5

Core curriculum subject. Role of materials in electrical engineering from the viewpoint of thermodynamics and statistical mechanics. Thermodynamics of materials interacting with electric, magnetic, mechanical, and thermal fields; applications to energy storage, conversion and control. Thermodynamic equilibrium; phase changes; chemical potential and Fermi energy. Connections to the microscopic; models of physical systems; particle in a box; multiparticle systems. Statistics of simple systems; Fermi-, Bose-Einstein and Maxwell-Boltzmann statistics; partition function. "Derivation" of macroscopic material properties from microscopic models; ideal gas, electron gas; system of dipoles; phonon and photon gases. *Epstein*

6.08T ***Molecular Engineering***
Prereq.: 8.051
Year: U (1, 2) 3–0–6

6.083T ***Molecular Engineering***
Prereq.: 8.05
Year: U (1, 2) 3–0–6

Core curriculum subject. Role of materials in electrical engineering from the viewpoint of thermodynamics and statistical mechanics. Thermodynamics of materials interacting with electric, magnetic, mechanical, and thermal fields; applications to energy storage, conversion, and control. Thermodynamic equilibrium; phase changes; chemical potential and Fermi energy. Connections to the microscopic models of physical systems; particle in a box; multiparticle systems. Statistics of simple systems; Fermi-, Bose-Einstein and Maxwell-Boltzmann statistics; partition function. "Derivation" of macroscopic material properties from microscopic models; ideal gas, electron gas; system of dipoles; phonon and photon gases. *(Not offered 1961–62.)*
Epstein (6.08T), McWhorter (6.083T)

6.081 ***Molecular Engineering***
Prereq.: 5.03, 6.06, 8.051
Year: U (1, 2) 4–0–5

Classroom part of 6.08. *Epstein*

6.082 ***Molecular Engineering Laboratory***
Prereq.: 6.081
Year: U (1, 2) 0–3–0

Experimental aspects of 6.08. *Epstein*

6.083 ***Molecular Science and Engineering***
Prereq.: 8.06
Year: U (1) 3–3–6
Core curriculum subject for Course VI, Program 2. Role of thermodynamics and statistical mechanics in electrical engineering as exemplified by materials in interaction with electric, magnetic, thermal, and mechanical fields. Reversible thermodynamics; state functions; criteria for equilibrium; chemical potential; phase changes. Irreversible thermodynamics; Onsager's relations; thermoelectricity and coupled flow phenomena, classical and quantum models of physical systems; elements of quantum statistics; partition function. Properties of electron gas, system of harmonic oscillators, electric and magnetic dipole systems; applications to ferroelectricity and ferromagnetism. *McWhorter*

6.083T *See above, following 6.08T.*

6.11 ***Project Seminar***
Prereq.: ——
Year: U (1) 2–0–4

6.12 ***Project Seminar***
Prereq.: ——
Year: U (2) 2–0–4
Special activity for students in Course VI-B. Study and evaluation of professional literature, oral presentation and active open discussion of topics drawn from and extending beyond those treated in the regular curriculum. Flexible organization, comprising a few students and staff with common areas of interest, under guidance of a staff member in an appropriate field. *Adler*

6.13 ***Electric and Magnetic Properties of Matter***
Prereq.: 6.033; 8.05 or 8.051
Year: U (2) 3–0–6
Discussion of electric and magnetic properties of matter using suitable microscopic models with particualr emphasis on solids. Electrical conductivity of metals, semiconductors, and insulators. Diamagnetism, paramagnetism, and ferro-magnetism. Electronic and ionic contributions to the dielectric constant. Some elements of statistical mechanics and thermodynamics. *A. C. Smith*

6.14 ***Electronic Networks and Devices***
Prereq.: 8.031, 18.03
Year: U (1, 2) 4–0–8
Introduction to basic network theory aimed at the analysis of electronic circuits. Illustration of network theorems and device behavior by examples of vacuum tube and transistor circuits. *Searle*

6.17 ***Illumination***
Prereq.: 8.03
Year: U (2) 3–0–6
For architects and engineers interested in the latest developments in the principles of architectural lighting. Daylight, lamps, calculation of light distributions, interflections, vision, color. *Moon*

6.18 ***Fundamentals of Electrical Engineering***
Prereq.: 8.03, 18.04
Year: U (1, 2) 3–2–5
Introductory subject for students not majoring in electrical engineering. Basic linear electric-circuit theory, elementary treatment of magnetic and dielectric materials and circuits, including energy and force relations, with applications to electromagnetic, electrostatic, and electromechanical components. Laboratory work to illustrate practical and theoretical questions considered in classroom. *Frazier, Kingsley*

6.19 ***Electronic Circuit Fundamentals***
Prereq.: 6.18
Year: U (1, 2) 3–2–5
For students not majoring in electrical engineering. Graphical and incremental methods for analysis of circuits involving thermionic tubes and semi-conductor devices. Study of rectifiers, basic vacuum tube and transistor amplifiers, basic feedback circuits, and elementary oscillators. Laboratory exercises to complement material presented in classroom. *Eager*

6.20 ***Electronic Control and Measurement***
Prereq.: 6.05
Year: U (1, 2) 3–0–6
Analysis and design principles of electronic systems for control and measurement. Input and output conversion transducers; grid-current at negative grids; direct-coupled amplifiers; differentiating and integrating circuits; amplitude, frequency, and phase modulation; frequency-selective amplifiers; phase- and frequency-sensitive detectors. Emphasis on the nonlinear properties of electron tubes and transistors either as limitations or as useful characteristics. *T. S. Gray*

6.202 ***Electronic Light Measurements***
Prereq.: 6.02 or 6.19
Year: U (1, 2) 2–2–5
Principles of analysis and design of electronic instruments for measurement of light in both steady and pulse form. Characteristics of radiation and light; phototube devices and associated amplifiers and integrating circuits; theory of electronic flash sources of pulsed light and their control. Illustrations from flash-photography applications to identify and determine position, velocity, and acceleration of mechanical objects. Frequent demonstration experiments to illustrate the various techniques to engineering and scientific measurements. *Edgerton*

6.213 ***Feedback Control Principles***
Prereq.: 6.05 or 6.18; 18.05
Year: U (1, 2) 3–2–5
An elective, terminal subject for seniors. Theoretical background for quantitative analysis and synthesis of feedback control systems. Laplace transform techniques for the formulation of transfer functions and manipulation of block diagrams of physical systems. Pole-zero configurations in the complex plane and transient response. Frequency response with emphasis on exact and approximate graphical techniques using logarithmic representation of transfer functions. Stability. Compensation to improve system behavior. Introduction to the study of discontinuous systems. Nonlinear systems studied through the use of describing function and phase-plane techniques. Case studies to illustrate engineering applications. Regular laboratory exercises. *L. A. Gould*

6.216 ***Dynamics of Electric Machines*** **(A, except for Course VI)**
Prereq.: 6.06 or 6.18; *6.213*
Year: U, G (2) 3–0–6
Treatment of rotating electric machines with emphasis on their dynamic performance in feedback systems. Equivalent-circuit models and block diagrams for synchronous, induction, and d-c machines including metadynes. Case studies to illustrate engineering applications. Solution of a dynamic problem on an analog computer as part of problem work. *Kingsley*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

6.227 *Engineering Electrodynamics*
Prereq.: 6.03
Year: U (2) 3–0–6
For undergraduates in electrical engineering. Applications of Maxwell's equations, particularly in the time-varying case. Electromagnetic waves, skin effect, superconductivity, waveguides, antennas. Alternate approach to electrodynamics by methods of Ampere, Gauss, and Ritz. *Moon*

6.232 *Electromechanical Control Components*
Prereq.: 2.02, 6.18; or 6.06
Year: U (2) 3–0–6
Problems of design and analysis of devices such as various types of servo motors, hysteresis motors, synchros, resolvers, differential transformers, tachometers, accelerometers, vibrometers, torque or force motors, magnetic suspensions, trigger magnets, and relays, including numerous electric field or duals of the magnetic field devices. Use made of all-electric-circuit analogs and the principle of duality. Illustrations based on actual apparatus. *Frazier*

6.241 *Engineering Problems*
Prereq.: 6.05, *6.06*
Year: U (1 or 2) 3–0–6
Elective subject given by notable practicing engineers to show the whole problem faced by the engineer. Discusses economic, legal, public relations, manufacturing, sales, and servicing aspects, as well as technical engineering. Registration Officers to be consulted about the field and instructor. *C. E. Tucker, White, Adler*

6.25 *Digital System Application*
Prereq.: 6.05 or 18.05
Year: U (1, 2) 3–0–6
Information processing and retrieval. Short review of Boolean algebra and logical design. Computer system organization and capacity. Construction of programming languages for the specification of algorithms. Simulation of physical systems, discussion of numerical techniques, and control of error. Laboratory work on the TX-0 and IBM 709 computers. *Teager*

6.251 *Digital Computer Programming Systems*
Prereq.: 18.04
Year: U (1, 2) 3–2–7
Basic principles of programming systems. Techniques for translation from problem-oriented languages to machine languages. Computer organization, programming, program planning and organization, assemblers, interpreters, compilers, automatic programming, debugging, and detection of logical errors. Laboratory work in the preparation and testing of programs for the IBM 709 computer. *Corbato*

6.252 *Digital Systems Engineering*
Prereq.: 6.05
Year: U (1, 2) 3–0–6
Introduction to basic concepts in design of digital systems, with emphasis on logical aspects. Brief treatment of computer organization and digital representation of information. Boolean algebra. Methods for logical synthesis of switching networks, both combinational and sequential. Utilization of electronic devices as bivalued elements in digital building blocks. Organization of these blocks into counters, arithmetic and control elements, and memory units. Self-checking and self-correction in digital systems. *Susskind, Hennie*

6.26 *Special Topics in Molecular Engineering*
Prereq.: 6.08 or 6.083
Year: U (2) 3–0–6
Elective for undergraduates in electrical engineering. Primarily concerned with physics of solids and applications of physical principles to device analysis and design. Varying subject matter from term to term. Representative topics to be included: ferroelectricity and ferromagnetism, principles and device applications; maser and parametric amplifiers; microwave ferrites; theory of conduction in metals and semiconductors; propagation of waves in periodic structures. *Epstein*

6.27 *Probabilistic Systems Analysis*
Prereq.: 18.04
Year: U (1) 3–0–6
Development of the theory of probabilistic discrete-state systems with particular reference to the fields of systems engineering and operations research. Subject matter ranging from algebra of events through distribution and characteristic functions to Markov processes, the theory of recurrent events, and random walks. Applications and illustrative material of an interdisciplinary character emphasizing the systems problems faced by all engineers. Exploration of pertinence to systems analysis of such operations research areas as search theory, mathematical programming, queuing theory, and computer simulation. *R. A. Howard*

6.281 *Principles of Wire Communications*
Prereq.: 6.02
Year: U (1) 3–0–6
Brief discussion of the principal telephone switching systems including the nation-wide toll-switching plan. Transmission characteristics of long lines with distributed parameters as a function of frequency; networks, loading, communications transformers, repeaters, balancing networks, insertion loss, carrier-current systems, distortion and its correction. Economic considerations effecting alternative plans are considered. *C. E. Tucker*

6.291 *Radar-System Engineering*
Prereq.: 6.05, *6.07*
Year: U (2) 3–0–6
Professional elective subject for undergraduates majoring in electrical engineering. Emphasis on engineering design of simple and complex electronic and electromechanical systems, with radar as a vehicle of study. Analysis and synthesis of master-pulse oscillators, cathode-ray-tube sweep generators, high-power pulse modulators, wide-band small signal amplifiers, antenna-control systems, r-f transmission and radiation systems. Factors influencing performance of over-all system. Problems resulting from interconnection of subsystems. *Reintjes*

6.300 *Communication and Control Circuit Theory*
Prereq.: 6.01
Year: U (1, 2) 3–0–6
Undergraduate elective for students majoring in electrical engineering. Continuation of discussions begun in 6.00 and 6.01; with emphasis on problems arising in the communications and electronic control fields. Correlation of the classical differential equation approach to time and frequency domain interrelationships with Fourier and Laplace methods, and application of these concepts to typical problems in the communications and control art. Numerical evaluation methods including impulse-train techniques. Introduction to network synthesis. *Guillemin*

6.311 *Principles of Communication*
Prereq.: 6.05, 18.04
Year: U (1) 3–0–6
Probabilistic formulation of the communications problem. Mathematical description of signals and noise. Elements of decision processes and performance of ideal receivers for interesting classes of modulation. Interchange of bandwidth and signal-to-noise ratio. Introduction to channel capacity, error-correcting codes, and error-free communication over noisy channels. *Wozencraft*

6.312 ***Communications System Engineering***
Prereq.: 6.20 or 6.311
Year: U (2) 3–0–6
Generation of radio frequencies, modulation, radiation, transmission and detection in communication systems. Interrelationship between the various components of a communication system in the light of the system application and the limitations imposed by the transmission medium and the available components. Investigation of a specific communication system problem to provide a common theme for the term's work. *Baghdady*

6.35 ***Acoustics***
Prereq.: 6.01, 18.05
Year: U (1) 3–1–6
Principles of sound propagation; sound generation; conversion between acoustical, electrical, and mechanical energy; and interaction of sound and man. Applications of these principles: design of microphones, loudspeakers, rooms for speech and hearing, and audio communications systems; noise and vibration control; underwater sound generation, propagation, and detection; uses of sound for analysis, testing and processing of materials. *Stevens*

6.36 ***Speech Communication***
Prereq.: 6.35 or 6.37
Year: U (2) 3–0–6
For well-qualified students with a serious interest in speech communication. Survey of structural properties of natural languages with special emphasis on the sound pattern. Acoustical theory of speech production: anatomical considerations; the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic. Perception of speech: the auditory capabilities of man; the role of set in perception; analysis by synthesis. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. *Stevens, Halle*

6.37 ***Sensory Communication***
Prereq.: 6.05
Year: U (1) 2–2–5
Designed to give an understanding of the emerging principles of man's sensory performance and to prepare the student for graduate study in the communication sciences. Introductory discussion of sensory transducers, sensory coding, and organization of the central nervous system in relation to signal processing. Stimulus-response relations derived from the behavior of the organism: responses to visual, auditory, and other sensory stimuli. Absolute and differential sensitivity. Psychophysical methods, including scaling techniques. Information handling capabilities and operating characteristics of human observers in various communication tasks. Temporal characteristics of sensory performance. Demonstration experiments. *Rosenblith, S. J. Mason*

6.38 ***Pulse Circuit Analysis***
Prereq.: 6.02
Year: U (2) 3–0–6
Analysis and design of wave shaping and pulse generating circuits which are used in radar, television, pulse communication, electronic computation, and cathode-ray instrumentation. *Zimmermann*

6.39 ***Image Transmission Systems***
Prereq.: 6.05
Year: U (2) 3–0–6
Historical development of image transmission systems. Mathematical description of images. Objective measures of image quality. Scanning and quantizing. Picture processing and coding. Transmission of video signals. Color systems. Term paper or project required. *Schreiber*

6.41 ***Introduction to Automatic Computation***
Prereq.: ——
Year: 1 (1, 2) 2–0–4
Principles of describing computation processes and programming digital computers to do them. Emphasis on concepts of computation processes and their realization by machine rather than on proficiency in art of programming. Stored program computers; binary, octal, and decimal number systems; practice in writing programs in machine language and in Fortran and running them on IBM 709; important kinds of programming languages; elementary treatment of theory of computation. Suitable elementary numerical problems in mathematics and physics; some non-numerical uses of computers. *J. McCarthy*

6.43 ***Introduction to Electrical Science***
Prereq.: 8.04 or 8.041
Year: U (1, S) 4–2–4

6.44 ***Introduction to Electrical Science***
Prereq.: 6.43
Year: U (2) 4–0–6
Two-term sequence for students not majoring in electrical engineering or electrical science. Introduction to the communications aspects of electrical science. Linear and nonlinear operations upon electrical signals. Synthesis of basic operations by means of electric and electronic circuits. Emphasis on transistor circuits. General properties of linear circuits and systems. The correlation concept. Analysis of signals and their spectra, some examples of random signals and noise. Modulation and detection processes. Fields and waves. Transmission and radiation of signals. *S. J. Mason, Rafuse*

6.50 ***Electrical Engineering Seminar*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Oral presentation of student's objectives and work in his field of specialty; participation in group discussions of reports by others. For doctoral candidates. *T. S. Gray*

6.521 ***Electrical Energy Conversion*** **(A)**
Prereq.: 2.40 or 6.08 or 8.07; 18.05
Year: G (1) 3–0–9
Introduction to theory and design of processes for direct electrical energy conversion. Typical processes: thermoelectric conversion, thermionic conversion, fuel cells, and photovoltaic conversion. From first principles to a discussion of such topics as electronic transport in solids using Boltzmann transport theory, quantum statistics, energy band theory of solids, electronic and thermal conduction processes, and thermionic emission. Introduction to irreversible thermodynamics and their use to describe device operations. Detailed treatment where possible of device characteristics including efficiency, power density, and terminal properties. *D. C. White*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

6.522 *Dynamics of Rotating Machine Systems* (A)
Prereq.: 6.06 or 6.063
Year: G (1) 3–2–7
Treatment of rotating electromagnetic energy converters by matrix and model concepts; dynamics of direct-current and alternating-current machines in control systems and electric power systems; performance and design of electrical apparatus to meet specifications in feedback control systems and power systems, taking account of the general physical limitations of materials. (*Not offered 1961–62.*) *Kingsley*

6.526 *Magnetohydrodynamic Energy Conversion* (A)
Prereq.: 6.03, 18.05
Year: G (2) 3–0–9
Introductory treatment of interactions between electrically conducting fluids and magnetic fields and their application to energy conversion device development. Review of fluid dynamics. Magnetohydrodynamic approximations, equations of motion, and important dimensionless groups. Properties of conducting fluids. Incompressible and compressible flows. Stability considerations. Wave motions in conducting fluids. Shock waves and their production. Energy conversion applications of magnetohydrodynamics. *Woodson, Jackson*

6.531 *Finite and Infinite State Machines* (A)
Prereq.: 6.254 or 18.20
Year: G (1) 3–0–9
Structure and behavior of finite-state machines and of finitely describable discrete machines having infinitely many states; the capabilities and limitations of such machines. Kleene's theorem. Related topics in switching circuit theory. Turing machines. Self-reproducing automata. Deterministic, nondeterministic, and probabilistic automata. *E. F. Moore*

6.534 *Games and Decisions* (A)
Prereq.: 6.311 or 6.573 or 18.18
Year: G (2) 3–0–9
Linear programming and the theory of games. Exposition of the theory and principal methods of solution. Dynamic programming. Approximation in policy space and other computational techniques. Introduction to Wald's statistical decision theory and sequential analysis. Applications to diode network models, optimal allocation, inventory and control problems, and problems of statistical estimation. *Arden, Arthurs*

6.536J *Systems Engineering and Operations Research* (A)
(Same subject as 15.594J)
Prereq.: 6.27 or 18.10 or 18.18; 18.05
Year: G (2) 3–0–9
Analysis of linear probabilistic systems. Application of linear system theory to the study of finite- and infinite-state, discrete- and continuous-time, stationary and nonstationary Markov processes. Optimization of probabilistic systems over short and long time periods by means of dynamic programming. Consideration of digital computer simulations as supplements to analytical investigations. Concurrent presentation of examples in the areas of system reliability, congestion processes, maintenance and replacement policies, search procedures, inventory control, and other operating problems of systems. Discussion of unsolved problems and promising areas of research. *R. A. Howard*

6.537T *Switching Circuits* (A)
Prereq.: 6.254 or 18.05
Year: G (1) 3–0–9
Description of combinational circuits by switching algebra; problems relating the simplification of algebraic form to the reduction of circuit complexity. Complete sets of elements; universal elements. The finite state machine model for sequential circuits; equivalence experiments and the simplification of terminal description. Realization of sequential circuits in pulsed or level form using bilateral and unilateral elements and elements with threshold, delay, and refractory period. Special limitations and advantages of synchronous and asynchronous circuits; races and hazards. Reliability and theoretical limitations of finite state machines. Special classes of sequential circuits, such as linear, self-synchronous, and information lossless. *Huffman, Arthurs*

6.539 *Mathematical Theory of Computation and Artificial Intelligence* (A)
Prereq.: 6.25 or 6.531 or 18.16 or 18.89
Year: G (1) 3–0–9
Mathematics of computation processes and computation languages. Synthesis of processes from elementary processes, and data spaces from elementary data spaces. Relations between programming and mathematical logic. Computing with symbolic expressions. Recent research into methods of making machines behave intelligently. (*Permission of instructor required.*) *J. McCarthy*

6.54 *Sampled and Quantized Systems* (A)
Prereq.: 6.571 or 6.601
Year: G (2) 3–0–9
Analysis of discrete linear systems in the time and z-transform domains. Consideration of discrete matrix systems describable by non-commutative flow graphs. Optimization of discrete systems with deterministic inputs. Investigation of the processes of sampling continuous signals and interpolating discrete signals. Analysis of mixed systems containing impulse modulators in addition to discrete and continuous filters. Exact and approximate inversion methods for transforms rational in both s and z. Determination of the response of discrete linear systems to discrete random signals by means of correlation functions and transforms; design of statistically optimum discrete systems. Analysis of amplitude quantization as a linear process in the probability domain. Discussion of recent research in dynamic programming and related areas as applied to system optimization. *R. A. Howard*

6.55 *Linear System Analysis* (A)
Prereq.: 6.02
Year: G (1) 3–0–9
Methods of analysis useful in the study of signals, systems and their response. Topological approach to generalized equilibrium equations for linear systems with nonbilateral and/or active multiterminal devices, duality, linear transformations. Differential equation solution for linear system response. Impedance and admittance properties relating the frequency and time domain aspects of physical circuit behavior. Normal coordinates and the degrees of freedom, topological versus dynamic independence, energy relations, normal coordinate transformations, passivity and stability. Fourier methods and their use in analysis and synthesis, including such topics as: convergence and approximation properties of Fourier series, their ability to characterize both aperiodic sampled functions as well as ones that are periodic and continuously defined. Approximation by finite trigonometric polynomials; Cesaro and other methods of summation. The concept of band-limited functions. Fourier and Laplace transforms and a comparison of network analysis by these methods with the classical differential equation solution showing their complete identity. Numerical evaluation methods using impulse-train techniques. Real part sufficiency and related topics. *Bers*

6.56 *Mathematical Methods in Electrical Engineering* (A)
Prereq.: 18.05
Year: G (1) 3–0–9
A subject emphasizing the physical and geometrical interpretations and their effective use in engineering analysis, rather than the abstract symbolic formalism of mathematical methods. Selected topics from: theory of determinants, matrices, linear transformations and quadratic forms; functions of a complex variable emphasizing the basic aspects for analysis of problems in the general field of electrical engineering as well as in the fields of communications and the electronic control art; approximation and convergence properties of Fourier, Laplace and Hilbert transforms, analytic and numerical methods for their evaluation. *Guillemin*

6.561 *Network Analysis and Synthesis* (A)
Prereq.: 6.30 or 6.55; 6.56
Year: G (1, 2) 3–0–9

6.562 *Network Analysis and Synthesis* (A)
Prereq.: 6.561
Year: G (1) 3–0–9
Advanced treatment of linear passive network theory with primary emphasis upon synthesis aspects; application to design of networks for prescribed driving-point and transfer characteristics; fundamental work of Foster, Cauer, Brune, and Darlington, as well as collaterally significant topics, illustrated with examples; synthesis of coupling networks for prescribed transfer characteristics, including RC as well as RLC, minimum-phase and non-minimum-phase types, filters, constant-resistance filter groups, and questions regarding the ultimate response characteristics obtainable from linear passive networks. Frequency and time domain aspects of the pertinent approximation problem. *Guillemin*

6.571 *Statistical Theory of Communication* (A)
Prereq.: 6.30 or 6.55 or 6.561 or 6.581
Year: G (1, 2) 3–0–9
Messages and noise as stationary random processes. Elementary probability theory, statistical characteristics of messages and noise, particularly correlation functions and spectra. Measurement of correlation functions. Detection of signals in the presence of noise by correlation. Determination of impulse response of linear systems by correlation. Theory of the statistical optimum filter, predictor, compensator, differentiator, and general linear system operator. Synthesis of optimum linear systems by normal and orthogonal functions. *Y. W. Lee*

6.572 *Statistical Theory of Nonlinear Systems* (A)
Prereq.: 6.571
Year: G (1, 2) 3–0–9
Operators and functionals. Functional power series representation of nonlinear systems. Stability and convergence. Functional representation when the input of a nonlinear system is a constant, a transient, a sinusoid, and a random process. An algebra for nonlinear systems. System transforms. Representation of nonlinear systems by an orthogonal system of functionals. The optimum nonlinear filter, predictor, feedback system, and general operator. The method of iteration in nonlinear theory. Special classes of nonlinear systems. Systems with multiple inputs. *Y. W. Lee*

6.573T *Random Signals and Noise* (A)
Prereq.: 6.05 or 6.053
Year: G (1, 2) 3–0–9
Introduction to probability and statistics. Random process models, with emphasis on shot and thermal noise. Signals and noise through linear and nonlinear devices, with application to the analysis of various modulation and detection systems. *Davenport, Siebert*

6.574 *Transmission of Information* (A)
Prereq.: 6.573 or 18.18
Year: G (1) 3–0–9
Introduction to the quantitative study of communication processes, with emphasis on the engineering of electrical communication systems that are both accurate and efficient. Definition of a measure of information and study of its properties; efficient representation of discrete message sources; communication channels and their capacity; message encoding and decoding in the presence of random disturbances; evaluation of bounds to the probability of decoding errors for simple channels. *Fano*

6.575 *Advanced Topics in Information Theory* (A)
Prereq.: 6.574
Year: G (2) 3–0–9
Further work in information transmission and coding theory based on 6.574. Participation by several staff members. *Elias*

6.576 *Statistical Theories of Signal Detection* (A)
Prereq.: 6.311 or 6.571 or 6.573T or 18.18
Year: G (1) 3–0–9
Review of random process models. Statistical hypothesis testing and decision theory, with application to signal detection and estimation problems in radar and communications. *Siebert, Davenport*

6.581 *Transients in Linear Systems* (A)
Prereq.: 6.01, 18.05
Year: G (1, 2) 3–0–9
Transient analysis using transform methods, but with emphasis on physical interpretation. Formulation of equations of lumped-constant linear approximations of physical systems; analogs. Development of the Laplace transformation and its inverse. Transforms of time functions; transformation of operations. System response to pulse, and pulse-train inputs; envelopes. Switching transients. Convolution processes in real and complex domains. Z transforms. Their use in treating sampled-time functions, sequences, difference equations, systems subject to cyclic switching, or comprising a chain of identical sections. Laplace transformation methods applied in solution of partial differential equations. *Gardner*

6.584 *Electromagnetic Theory* (A)
Prereq.: 6.02, 18.05
Year: G (1) 3–0–9
Selected topics from fields, energy and forces, energy transmission and radiation, treated from an advanced viewpoint. (*For first year graduate students.*) *Chu*

6.586 *Engineering Applications of Field Theory* (A)
Prereq.: 18.04
Year: G (2) 3–0–9
Engineering solutions of Laplace, Poisson, diffusion, and wave equations by separation of variables in a large number of coordinate systems. Practical applications to electrostatic, magnetic, thermal, and electromagnetic-wave problems. *Moon*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

6.59 *Bioelectric Signals* (A)
Prereq.: 6.37
Year: G (2) 3–0–9
Introduction for graduate students in the physical and communications sciences. Basic phenomena of the electrophysiology of the nervous system. Electrical activity related to sensory stimuli with emphasis upon the auditory and visual systems. Evoked responses at various levels of the nervous system and their relation to ongoing activity. Electronic recording and computing devices in the study of bioelectric signals. Mathematical models for the behavior of sensory systems. Organisms in communication processes and systems. *Rosenblith*

6.592 *Analytical Models for Human Processing of Sensory Inputs* (A)
Prereq.: 6.37
Year: G (2) 2–0–7
Evaluation and design of research procedures for the simulation of human perceptual processes. Review of relevant literature from psychophysics and theory of perception, considering both human perception and the evidence from the study of lower organisms. Application of this information to a critical evaluation of recent work in machine simulation of human perceptual processes, emphasizing studies of pattern recognition, abstracting, self-organizing systems as perceptual models, etc. Design of experimental research projects utilizing the technique of machine simulation with the goal of providing a perceptual model that satisfies the known constraints of human physiology and psychology.
Eden, Chomsky

6.601 *Feedback Control Theory* (A)
Prereq.: 6.05, 18.05
Year: G (1) 3–0–9
Models for physical systems, block diagrams, Laplace and Fourier transforms, stability criteria, transient response, frequency response, performance indices, and compensation schemes leading to trial-and-error design procedure for linear control systems. Properties and effects of stochastic signals. Introduction to nonlinear systems, sampled- and quantized-data systems, and optimization theory. Newton, Gould, and Kaiser, *Analytical Design of Linear Feedback Controls.* *L. A. Gould*

6.602 *Nonlinear Control Systems* (A)
Prereq.: 6.601
Year: G (2) 3–0–9
Basic nonlinear differential equation theory. Analytical graphical, and approximation techniques for studying the behavior of nonlinear systems. Application of phase-plane and describing-function techniques in analysis of control systems containing nonlinearities. Design of relay-type control systems. Discussion of adaptive control systems and other advanced topics in nonlinear theory. *Seifert*

6.606 *Control System Synthesis* (A)
Prereq.: 6.601
Year: G (2) 3–0–9
Synthesis of control systems with emphasis on use of analysis of mathematical models to guide engineering designs. Mathematical optimization theory presented as theoretical basis for synthesis of stationary and time-varying linear control systems. Signal characteristics, mean-square, integral-square error and other system performance criteria together with component limitations considered in formulating optimization procedures. Effects of sampling, nonlinearities, and switching discussed. Selected topics in components used in control systems: sensing devices, electric and hydraulic servomotors, gearing, signal and power amplifiers, carrier and non-carrier compensating networks. Opportunities for case studies, laboratory and special project work provided. *Newton*

6.607 *Feedback Control Laboratory* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised investigation of special topics in feedback control system analysis and synthesis, laboratory investigations supported by library research and analytical work utilizing the facilities of the feedback control laboratory. Program and hours to be arranged with interested staff member, subject to approval of instructor. *Newton*

6.608 *Process Control* (A)
Prereq.: 6.601, 18.15
Year: G (2) 3–0–9
Control of industrial processes with emphasis on applications in the chemical and petroleum industries. Development of lumped and distributed dynamic models of chemical processing units. Partial differential equations of linear transport processes and methods of solution. Behavior of chemical reactors characterized by Arrhenius-type rate expressions and product-type nonlinearities. Numerical methods of solution. Conventional process controller design with examples of pneumatic, electronic, and electro-hydraulic controllers. Optimization theory for interconnected processing systems. Static optimization through surface searching: methods of steepest descent, relaxation techniques, randomized search procedures. Formulation of minimum-cost control problem as a dynamic optimization problem. Solution through the application of the calculus of variations and dynamic programming. Applications to batch, continuous, and cyclic processes. Control computers, control programming, and optimization of programs in time. Synchronous and asynchronous programs and their effects on dynamic accuracy and stability developed through sampled-data theory. *L. A. Gould*

6.61 *Production and Application of Atomic Radiations* (A)
Prereq.: 6.03 or 8.08
Year: G (2) 3–0–6
Electrical processes in high vacuum, compressed gas, and solid dielectrics under high electrical stress. Principles of machine sources of intense megavolt radiation beams including the Van de Graaff electrostatic, resonance transformer, betatron, synchrotron, and microwave linear accelerators; properties of high-energy electrons, X-rays, positive ions, and neutrons; methods of controlling and measuring these forms of ionizing energy; their interaction with living and nonliving matter; radiation techniques in diagnosis and treatment of disease, radiography of metal sections, sterilization of drugs and tissue, preservation of food, production of isotopes, polymerization, and crosslinking of hydrocarbons. *Philp*

6.621 *Microwave Circuits* (A)
Prereq.: 6.07
Year: G (1) 3–2–7
Analysis of electromagnetic wave propagation in uniform cylindrical waveguides; reduction of waveguide and discontinuity problems to equivalent transmission line and network problems; obstacles as matching elements. Cavity resonators; perturbation theory. Multiple waveguide junctions; matrix algebra techniques. Laboratory experiments. *Bers*

6.622 *Antennas* (A)
Prereq.: 6.07
Year: G (2) 3–0–9
General theory of radiation and its application to the analysis of representative types of antennas; emphasis placed on the design of antenna arrays, microwave reflectors, and lenses. *Chu*

6.623 *Principles of Pulse Circuits* (A)
Prereq.: 6.05
Year: G (1) 3–0–9
Analysis and design of overdriven circuits, multivibrators, blocking oscillators, and other high-speed circuits used for waveshaping and timing in pulsed and digital systems. Graphical and numerical methods, piecewise-linear, and other approximations useful in nonlinear analysis. Applications to typical system design problems. *Zimmermann*

6.625 *Fundamentals of Radio Astronomy* (A)
Prereq.: 8.051
Year: G (1) 3–0–9
Techniques of detection and measurement of thermal radiation, concept of "antenna temperature," parabolic antennas and interferometers. Emission and absorption of radio energy in stellar and planetary atmospheres, gaseous nebulae, and the interstellar medium. Detailed development of emission mechanisms, including free-free transitions, line radiation at 21 cm and other wavelengths, synchrotron radiation using classical relativistic electrodynamics. Theory and results of radio observations of the moon, planets, sun, discrete galactic sources, galactic background radiation, extra-galactic sources. Impact of radio astronomy on galactic structure, origin of cosmic rays, cosmology. Radio astronomical observations and experiments from space vehicles. (*No prior knowledge of astronomy or astrophysics required.*) *Barrett*

6.626 *Modulation Theory and Systems* (A)
Prereq.: 6.311
Year: G (1) 3–0–9
Detailed study of the signaling, modulation, and multiplexing problems; conventional and unconventional types of modulation; and factors affecting the choice of the type of modulation in the design of a communication system. Such topics as: characterization of signals and of messages; properties of modulated sinusoids and pulse trains; the conditions for low-distortion transmission of modulated sinusoids through linear, frequency-selective systems; critical evaluation of the effect of the signal-processing techniques at the receiver upon the sensitivity of each type of modulation system to interference from undesired signals, to random noise, and to impulsive disturbances; and the effects of transmission media, fading, and diversity techniques. *Baghdady*

6.627 *Propagation of Radio Waves I* (A)
Prereq.: 6.07
Year: G (1) 3–0–9

6.628 *Propagation of Radio Waves II* (A)
Prereq.: 6.627
Year: G (2) 3–0–9
Study of the effects of the medium on the propagation of electromagnetic radiation with applications to communications and to the determination of the characteristics of the medium itself. Introduction to basic processes in the upper atmosphere, followed by a treatment of the formation and properties of the ionospheric layers. Analysis of propagation in a spatially varying medium, with application to tropospheric and ionospheric effects, including considerations of magneto-ionic theory. Investigation of the nature of atmospheric and ionospheric irregularities and the scattering of radio waves by these irregularities. Other possible applications of the general theory: special topics of current interest such as cosmic noise, ionospheric storms and motions, reflections from meteor trails and the aurora, whistlers, etc. (*Not offered 1961–62.*) *Loewenthal*

6.629 *Radar System Engineering* (RA)
Prereq.: 6.02, 6.213
Year: G (1) 3–0–9
Fundamental principles of pulsed radar; analysis of radar as a data-gathering device for more complex systems; factors influencing radar-system performance; analysis and synthesis of radar subsystems. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *Reintjes*

6.631T *Plasma Dynamics* (A)
Prereq.: 6.03, *6.634*, 8.05
Year: G (1) 3–0–6
Foundations for the production and manipulation of ionized gases. Particle interactions with electromagnetic fields. Discussion of collision theory, ionization, and breakdown. Development of macroscopic transport parameters from the Boltzmann equation. Properties of plasmas and sheaths with and without magnetic fields. Methods of heating, containing, and accelerating plasmas. Plasma oscillations, wave propagation, and other topics as time permits. *Whitehouse*

6.632 *Electronic Instrumentation and Control* (A)
Prereq.: 6.05
Year: G (1, 2) 3–0–9
Transistors, other solid-state devices, and electron tubes in electronic instrumentation for control and measurement. Electronic conversion transducers; direct-coupled, pulse, and signal-processing amplifiers; modulators and demodulators; monostable and bistable switching circuits; gates; coincidence circuits; random-event counting and count-rate circuits. Illustrations from such applications as time-interval and frequency measurements, high-speed counting and recording instruments, computer components, strain gages, tachometers, and nuclear-reactor control. *T. S. Gray*

6.634 *Plasma Dynamics Graduate Laboratory* (A)
Prereq.: *2.495* or *6.631T* or *8.231* or *22.61*
Year: G (1) 1–4–4
Laboratory investigations in the area of plasma dynamics designed to facilitate the learning of new concepts and to provide experience with diagnostic techniques for independent research and theses. Selection of experiments from the areas of electrical discharges, plasma physics, magnetohydrodynamics, power generation, fusion, propulsion, and propagation. Preparation by an interdepartmental committee of lectures and experiments designed for graduate students of science and engineering to develop an understanding of experimental plasma dynamics. *Whitehouse*

6.635 *Transistors* (A)
Prereq.: 6.05; 6.08 or 6.64 or 8.051 or 8.08
Year: G (1) 3–0–9
Primarily for graduate students in electrical engineering. Physical foundations of transistor action, developing the terminal properties of the transistor as an electronic device. Brief qualitative introduction to the concepts of free electrons and holes in semiconductors; elementary quantitative treatment of electrical conductivity as a function of impurity concentration and temperature; drift, diffusion and continuity relations governing carrier flow out of thermal equilibrium; derivation of the d-c and incremental a-c electrical characteristics of the planar junction diode and junction transistor; equivalent circuits; implications of the model for device performance and limitations; additional physical factors affecting small- and large-signal performance; related and improved devices, as time permits. *Adler*

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6.636 *Semiconductor Electronics* (A)
Prereq.: 6.635
Year: G (2) 3–0–9
Principles and application of some of the electronic properties of semiconductors important for devices: avalanche and tunneling breakdown in p-n junctions, avalanche diodes and transistors, tunnel diodes, statistics of recombination and trapping, PNPN switches, mobility in high electric fields, field effect transistor. Surface phenomena. Some details of band structure in Ge, Si, and related semiconductors. *McWhorter*

6.637 *Beam-Type Microwave Tubes* (A)
Prereq.: 6.07 or 6.322; 6.621
Year: G (2) 3–0–9
Interactions between electron beams and stationary or traveling electromagnetic fields; space charge waves, cyclotron waves; coupling of modes in propagating systems; kinetic power theorem; propagation in plasma waveguides. *Smullin*

6.64T *Insulators, Semiconductors, and Metals* (A)
Prereq.: 8.04 or 8.041
Year: G (2) 3–1–8
Study of atoms and molecules and their behavior in gases, liquids, and solids from the unifying standpoint of the interaction of matter with electric and magnetic fields (polarization, magnetization and conduction). Short survey of the macroscopic theory; effects of electric and magnetic moments from their initial individual appearance in spectroscopy to their final concerted action in ferroelectrics and ferromagnetics; the laws of motion of electrons and ions from insulators to semiconductors to metals. Interdepartmental subject for graduate students of science and engineering, designed to lead to an understanding of present-day research problems in the field of molecular science and molecular engineering. *von Hippel*

6.641 *Laboratory Seminar in Molecular Engineering* (A)
Prereq.: 6.08
Year: G (1) 0–8–4
Experimental investigations of the properties of materials; brief lectures on the basic theory of material properties and references to the literature; experiments closely related to current research in this area in the Department and expected to lead to thesis topics in the area; emphasis on the capabilities and limitations of modern methods of solid state experimentation. *A. C. Smith*

6.642 *Wave Nature of Matter* (A)
Prereq.: 6.08
Year: G (1) 3–0–9
Wave theory, wave packets, transforms, eigenfunctions. Statistical nature of wave mechanics: expectation values and standard deviations, the uncertainty principle. Electrons in small fields, energy barriers and periodic-potential fields. Conductors and semiconductors, field emission. Operators and commutators, discrete systems: harmonic oscillator, rotor, hydrogen atom. Modes of oscillation, selection rules. The hydrogen molecule-ion, bonds and bands. Electron spin, correlated and uncorrelated precession, exclusion principle, perturbation theory, the helium atom. Hybrid orbitals, crystalline field splitting. *Loeb*

6.644 *Microwave Magnetics* (A)
Prereq.: 6.08
Year: G (2) 3–0–9
Energy, momentum characteristics of radiation; atomic oscillators, electric and magnetic; relaxation of atomic systems; fluctuations, noise; propagation in dielectrics; complex permitivity, permeability; gyrotropic media, non-reciprocity; paramagnetics, ferro-, antiferro-, ferrimagnetics; magnetic resonance; spin wave spectra; nonlinear response, mode coupling, parametric amplification; saturation, spin inversion, quantum amplifiers. *Miles*

6.646 *Conduction Processes in Solids* (A)
Prereq.: 6.08 or 8.07; 6.635 or 6.642 or 8.361 or 8.731
Year: G (2) 3–0–9
Topics in transport theory, including crystal symmetry, Onsager relations, brief discussion of electronic energy bands in solids, Boltzmann transport theory, electronic scattering mechanisms; detailed application to semiconductors for which the problems are of intermediate difficulty. Discussion of quantum effects and non-equilibrium thermodynamical methods, as time permits. *Adler, A. C. Smith*

6.647 *Seminar in Fundamental Properties of Materials* (A)
Prereq.: 6.642 or 8.361
Year: G (1) 2–0–7

6.648 *Seminar in Fundamental Properties of Materials* (A)
Prereq.: 6.647
Year: G (2) 2–0–7
Study of Germanium undertaken by investigating significant experimental measurements that have been made and using results to evolve a complete theoretical model for Ge. Measurements of the conductivity, magnetic susceptibility, cyclotron resonance, microwave, infra red, and optical properties, the transport and lattice vibrations. From these a theoretical model for Ge constructed in terms of energy bands, effective mass theory, role of spin orbit coupling, excitons, impurity levels, interaction between electrons and phonons. Seminar aimed at showing how one applies a formal background in solid state to the planning and interpretation of experiments. Guest lecturers to speak on their specialties. *Pratt*

6.65 *Quantum Theory of Magnetism* (A)
Prereq.: 8.361
Year: G (2) 3–0–9
Magnetic properties of isolated atoms and ions. Crystal field theory. The spin Hamiltonian. Optical properties of paramagnetic crystals. Spin paramagnetism of metals. Diamagnetism of solids. The de Haas-van Alphen effect. Cyclotron resonance and magneto-optic effects in semiconductors. Ferromagnetic exchange interactions. The Weiss and Heisenberg theories of ferromagnetism. The Bethe-Peierls-Weiss theory. Energy band theory of ferromagnetism. Superexchange coupling in antiferromagnetism. Ferrimagnetism. *Pratt*

6.66 *Engineering Applications of Tensors* (A)
Prereq.: 8.041
Year: G (1) 3–0–9
Exploration of the value of matrices and tensors in the solution of engineering problems. Applications to networks, electromagnetic theory, inhomogeneous and anisotropic media, elasticity, optics, and color. *Moon*

6.68 *Special Problems in Electrical Engineering* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Opportunity for individual study, under a staff member, of advanced subjects related to electrical engineering not otherwise included in the curriculum. Program to suit individual requirements by the student and staff members interested, subject to approval of the professor in charge. *Gardner*

6.692 ***Advanced Engineering Acoustics*** **(A)**
Prereq.: 6.35
Year: G (2) 3–0–9
Application of network techniques to the design of loudspeakers, microphones and enclosures. Control and utilization of wavefront geometry; directivity, distance localization. Analysis of noise fields in the space, time and frequency domains, classical statistics, correlation, filtering and scanning. Power flow considerations, handling of power flow, concept of a balanced noise-control solution. Geometric acoustics, ray diagrams, image spaces and absorption perturbations. Analysis of logical and physical conditions: scaling and model theory, dimensional analysis. *Baruch*

6.70 ***Experimental Electronics***
Prereq.: 6.01 or 6.14
Year: U (2) 1–4–1
Basic laboratory oriented subject combining experimental studies of electronic circuits with an introduction to basic electronic components and instruments. Laboratory work consisting primarily of projects requiring a combination of theoretical analysis and experimental measurements. *Thornton*

6.71 ***Electronic Circuits and Signals Laboratory***
Prereq.: 6.01 or 6.02
Year: U (1) 1–4–1
Required laboratory for electrical engineering students. Experiments on electric and electronic circuits and systems. *Schreiber*

6.72 ***Electromagnetic Laboratory***
Prereq.: 6.03T
Year: U (2, S) 1–4–1
Required laboratory for electrical engineering students. Experiments and projects on measurements of electromagnetic fields and waves. *Smullin*

6.73 ***Advanced Electrical Engineering Laboratory***
Prereq.: 6.72
Year: U (1) *Arr.*
Required laboratory for electrical engineering students. Experiments and projects on advanced level. Minimum 6 units. (*Not offered 1961–62.*) *Elias*

6.74 ***Advanced Electrical Energy Conversion Laboratory*** **(A)**
Prereq.: 6.06
Year: G (1 or 2) *Arr.*
Graduate subject planned for the individual student; special problems on electrical energy converters and modulators. *D. C. White*

6.80 ***Electrical Circuits Laboratory***
Prereq.: ——
Year: U (1 or 2) *Arr.*
Experimental work at the sophomore level on electric circuits, meters, basic measurements, etc. *Thornton*

6.81 ***Electronics Laboratory***
Prereq.: 6.02
Year: U (1 or 2) *Arr.*
Experimental work on electronic circuits at the junior and senior levels. *Thornton*

6.86 ***Electrical Energy Conversion Laboratory***
Prereq.: 6.01 or 6.18
Year: U (1 or 2) *Arr.*
For electrical engineering students who wish laboratory work in addition to that included in 6.03, 6.06, and 6.08, and other students requiring a special program in energy-conversion laboratory. Arranged to suit the requirements of the individual student. *Woodson*

6.90 ***Industrial Project at the General Electric Company***
Year: U (1) 0–9–0
Project to satisfy requirements for S.B. thesis. A report on the project required in the nature of a thesis report. *Reintjes*

6.901–6.903 ***Industrial Practice at the General Electric Company***
Year: U (1, 2, S) 0–9–0
6.904 ***Industrial Practice at the General Electric Company***
Year: G (S) 0–9–0
Locations at Philadelphia, Pittsfield, Schenectady, Syracuse, or Utica. Work in electronic circuitry, solid state physics, control and guidance systems, and computer applications as applied to research and development of commercial and government communication and control systems and ordnance equipment. *Reintjes*

6.905–6.907 ***Industrial Practice at the International Business Machines Corporation***
Year: U (1, 2, S) 0–9–0
6.908 ***Industrial Practice at the International Business Machines Corporation***
Year: G (S) 0–9–0
Work at an IBM plant in Endicott, Kingston, Ossining, Owego, or Poughkeepsie. Student participation in computer development, design, and application. Work in advanced circuit theory, solid-state physics, game theory. *Reintjes*

6.909 ***Industrial Project at the International Business Machines Corporation***
Year: U (1) 0–9–0
Project to satisfy requirements for S.B. thesis. A report on the project required in the nature of a thesis report. *Reintjes*

6.911–6.913 ***Industrial Practice at the Boston Edison Company***
Year: U (1, 2, S) 0–9–0
6.914 ***Industrial Practice at the Boston Edison Company***
Year: G (S) 0–9–0
Work location in Greater Boston. Work in the planning, design and operation of a large-capacity, investor-owned, electric utility system of compact area. Automation through applications of computers, data-logging, and remote controls (carrier and microwave); sophisticated economic justification studies including net worth, complex statistical analyses, and probability techniques. *Reintjes*

6.919 ***Industrial Project at the Boston Edison Company***
Year: U (1) 0–9–0
Project to satisfy requirements for S.B. thesis. A report on the project required in the nature of a thesis report. *Reintjes*

6.921–6.923 ***Special Industrial Practice***
Year: U (1, 2, S) 0–9–0
6.924 ***Special Industrial Practice***
Year: G (S) 0–9–0
Special assignments outside the regular Cooperative program. *Reintjes*

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6.931–6.933 ***Industrial Practice at the Raytheon Company***
Year: U (1, 2, S) 0–9–0

6.934 ***Industrial Practice at the Raytheon Company***
Year: G (S) 0–9–0

Work at one of the Raytheon Laboratories (Newton, Burlington, Wayland, Sudbury, Bedford). Assignments involving circuit analysis and design as applied to communication and control systems; or, research and development activity in the fields of solid state physics; electro- and ferro-magnetics; acoustics, and microwave electronics. *Reintjes*

6.939 ***Industrial Project at the Raytheon Company***
Year: U (1) 0–9–0

Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

6.941–6.943 ***Industrial Practice at the Bell Telephone Laboratories, Inc.***
Year: U (1, 2, S) 0–9–0

6.944 ***Industrial Practice at the Bell Telephone Laboratories, Inc.***
Year: G (S) 0–9–0

Work at a Bell Telephone Laboratory [Murray Hill or Whippany (N. J.), or New York City]. Work in all areas of circuit development pertaining to communication systems. Solid-state physics, microwave propagation, transistor logic circuitry, digital comparators, ferroelectrics, switching systems, electronic instrumentation, push-button dial systems, and pulse transmission systems all available as projects in the development and application stages. *Reintjes*

6.949 ***Industrial Project at the Bell Telephone Laboratories, Inc.***
Year: U (1) 0–9–0

Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

6.951–6.953 ***Industrial Practice at the General Radio Company***
Year: U (1, 2, S) 0–9–0

6.954 ***Industrial Practice at the General Radio Company***
Year: G (S) 0–9–0

Work for the General Radio Company in West Concord. Assignments to manufacturing departments and development laboratories in manufacture of electronic instruments. Opportunity for laboratory assignments in fields of pulsing, counters, recorders, sound measurement, signal generators, bridges, laboratory standards, stroboscopy. *Reintjes*

6.959 ***Industrial Project at the General Radio Company***
Year: U (1) 0–9–0

Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

6.961–6.963 ***Industrial Practice at the Philco Corporation***
Year: U (1, 2, S) 0–9–0

6.964 ***Industrial Practice at the Philco Corporation***
Year: G (S) 0–9–0

Work for the Philco Corporation in Philadelphia. Work in transistor circuitry, television development, microwave systems, government communication and detection systems, computer techniques, solid-state physics, and analytical studies. *Reintjes*

6.969 ***Industrial Project at the Philco Corporation***
Year: U (1) 0–9–0

Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

6.971–6.973 ***Industrial Practice at the American Electric Power Service Corporation***
Year: U (1, 2, S) 0–9–0

6.974 ***Industrial Practice at the American Electric Power Service Corporation***
Year: G (S) 0–9–0

Work at a plant of the American Electric Power Service Corporation (Canton, Fort Wayne, New York City, or Roanoke). Work associated with the operation and planning of a large multi-state power generation and distribution system. Challenging assignments in computer solutions (analog and digital) of power flow, stability, regulation, and economy loading in a large network. Microwave communication systems, electronic relaying, research in corona and extra-high voltages. Opportunities for outside experience during earlier terms. *Reintjes*

6.979 ***Industrial Project at the American Electric Power Service Corporation***
Year: U (1) 0–9–0

Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

6.981–6.983 ***Research and Development at the Naval Ordnance Laboratory***
Year: U (1, 2, S) 0–9–0

6.984 ***Research and Development at the Naval Ordnance Laboratory***
Year: G (S) 0–9–0

Work at the Naval Ordnance Laboratory in Silver Spring, Maryland. Assignments in physics and electrical engineering as applied to development of air and underwater ordnance of U. S. Navy. Studies of Earth's magnetic field, solid-state physics, ballistics, supersonic and hypersonic aerodynamics, microwave circuitry, and entire range of transient measurements. Application of symbolic logic to the development of special purpose data processing equipment. Students offered one-half junior and senior tuition and full graduate tuition in exchange for eighteen months Naval duty following graduation. Acceptance optional. *Reintjes*

6.989 ***Industrial Project at the Naval Ordnance Laboratory***
Year: U (1) 0–9–0

Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

6.991–6.993 ***Research and Development at the Air Force Cambridge Research Laboratories***
Year: U (1, 2, S) 0–9–0

6.994 ***Research and Development at the Air Force Cambridge Research Laboratories***
Year: G (S) 0–9–0

The Electronics Research Directorate of the Air Force Cambridge Research Laboratories conducts fundamental research in those physical and allied sciences likely to enhance Air Force capability in electronic and electromagnetic technology. Assignments available in areas of computer principles and techniques (including related mathematical sciences, data processing and simulation); solid-state electronics, nucleonics, and physical electronics (to discover, create, or improve electronics materials); electromagnetic radiation and microwave physics (leading to improved antenna systems); recognition and detection techniques including data processing (for collection of data on objects and phenomena above surface of earth); studies of terrestrial and extraterrestrial emission and propagation of electromagnetic waves (in order to obtain fundamental knowledge required for design of electronic equipment in terrestrial, aeronautical, and astronautical environments); communications systems and techniques (in terrestrial and extraterrestrial environments). *Reintjes*

6.999 ***Industrial Project at the Air Force Cambridge Research Laboratories***
Year: U (1) 0–9–0
Project to satisfy requirements for S.B. thesis. A report required in the nature of a thesis report. *Reintjes*

7.
Biology

7.00 ***Perspectives in Life Science***
Prereq.: ——
Year: 1 (2) 3–0–3
Lectures and demonstrations presenting the place of man in the world of living organisms; factors important in man's successful adaptation to his external environment, animate and inanimate; and the processes which make possible the various functions of man's body in health and disease including major concepts of genetics, growth, development, and physiology. Concluding lectures on the growing importance of biophysics and biochemistry in the shaping of modern biological concepts — (biology at the molecular level) and the outlook for theoretical biology. *B. S. Gould*

7.01 ***General Biology I***
Prereq.: ——
Year: U (1) 3–0–4

7.02 ***General Biology II***
Prereq.: 7.01
Year: U (2) 3–0–4
Introduction to the study of plant and animal organisms, including man. *First Term:* Nature of life, physical and chemical structure of protoplasm; form and structure of plants; cells and cell structure; relations and structure of cells, tissues and organs of plants; plant physiology; review of plant kingdom; systems of the animal body (anatomy-physiology). *Second Term:* Review of the animal kingdom growth and reproduction in plants and animals, heredity, evolution, plant and animal classification, principles of ecology, plant and animal diseases, immunity, viruses, history and perspectives of biology. *Herbert (7.01), Rich (7.02)*

7.011 ***General Biology Laboratory I***
Prereq.: ——
Year: U (1) 0–3–0

7.021 ***General Biology Laboratory II***
Prereq.: 7.01
Year: U (2) 0–3–1
Laboratory exercises to illustrate the principles in 7.01 and 7.02. *Herbert (7.011), Lettvin (7.021)*

7.03T ***Genetics and Cytology***
Prereq.: 7.02, 7.021
Year: U (1) 2–0–4
The cell as a structural and functional unit, with an introduction to the principles of cytochemistry. Discussion of the roles of both the nucleus and cytoplasm in cellular processes and in relation to the phenomenon of heredity, variation and mutation in organisms. *Baglioni*

7.031 ***Genetics and Cytology Laboratory***
Prereq.: 7.02, 7.021, *7.03T*
Year: U (1) 0–4–0
Laboratory designed to illustrate principles of genetics and cytology. *Baglioni*

7.04 ***Developmental Biology***
Prereq.: 7.03T, 7.031
Year: U (2) 2–6–4
Basic concepts and principles of growth and differentiation, emphasizing the experimental method in the development of animals from germ cells to organ systems. *Bell*

7.05 ***General Biochemistry***
Prereq.: 5.41, 5.62
Year: U (1) 3–0–6
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.
Ingram, G. M. Brown

7.051 ***General Biochemistry Laboratory***
Prereq.: *7.05*
Year: U (1) 0–8–0
Laboratory exercises to illustrate principles discussed in 7.05. *B. S. Gould, G. M. Brown*

7.06 ***General Physiology***
Prereq.: 7.02
Year: U (2) 3–0–6
General principles in vertebrates and invertebrates of cell maintenance, transport, irritability, contraction, and cellular interaction. Relation of form and function. Mechanisms by which the animal interrelates with its internal and external environment. *P. D. Wall*

7.061 ***General Physiology Laboratory***
Prereq.: *7.06*
Year: U (2) 0–6–0
Laboratory investigation of physiological processes.
Lettvin

7.08 ***Introduction to Biophysics***
Prereq.: 7.00 or 7.02; 8.04
Year: U (2) 2–0–4
Application of the analytical methods of the physical sciences to biology. Emphasis on the molecular aspects of the control systems governing the growth, development and functioning of living organisms. *Levinthal, Dintzis*

7.13 ***Genetics***
Prereq.: 7.02
Year: U (2) 2–0–4
Facts and theories of heredity; their relation to the present state of biological theory in general. *Baglioni*

7.21T ***General Microbiology***
Prereq.: 7.03T, 7.031, 7.05
Year: U (1) 3–0–6
Properties of unicellular organisms, especially bacteria: composition, metabolic activities, and structural organization. Microorganisms as model systems for the study of cellular growth and its physiological basis. Variation, heredity, and the organization of the genetic system in bacteria. Comparative discussion of cellular organization in bacteria, in other microbes, and in multicellular organisms. *Luria, Magasanik*

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7.22 *Experimental Microbiology* (A)
Prereq.: 7.21
Year: G (2) 1–6–2
Discussions, laboratory exercises, and projects introducing the student to experimentation with microorganisms. *Magasanik, Luria*

7.23 *Microbial Physiology* (A)
Prereq.: 7.05, 7.21
Year: G (2) 2–0–4
Principal chemical processes responsible for the function and growth of microbial cells. Genetic and environmental control of cellular functions. Chemical activities of microorganisms in a framework of comparative physiology and biochemistry. *Magasanik*

7.31 *Biology Seminar* (A)
Prereq.: 7.06
Year: G (1) 2–0–4

7.32 *Biology Seminar* (A)
Prereq.: 7.06
Year: G (2) 2–0–4
Designed to give graduate students experience in critical evaluation of research and in public speaking by presenting oral reports before staff and students. *Bell*

7.35 *Cellular Physiology* (A)
Prereq.: 7.06
Year: G (1) 2–0–4
Recent advances in one of the following fields: contractility, transport, coordination (nerve and endocrines), or growth and development. Selection of a different topic each year. *Staff*

7.36 *Advanced Neurophysiology* (A)
Prereq.: 7.06
Year: G (1) 2–0–4
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. *P. D. Wall*

7.50 *Physical Chemistry of Proteins* (A)
Prereq.: 7.05
Year: G (2) 2–0–4
Corpuscular proteins including fractionation, physical-chemical characterization, internal structure, surface structure, and modification by physical and chemical agents. Discussion of protein interactions such as the corpuscle, fibril transformation, and antigen-antibody interactions. *D. F. Waugh*

7.68 *Intermediary Metabolism* (A)
Prereq.: 7.05
Year: G (2) 3–0–6
Survey of chemical pathways of metabolism with emphasis on recent literature in biochemistry. Biosynthesis of important tissue constituents such as amino acids, proteins, lipids, nucleic acids, vitamins, and porphyrins. Mechanisms of biochemical reactions. *Buchanan, Robbins*

7.69 *Seminar in Biochemistry* (A)
Prereq.: 7.05
Year: G (2) 2–0–4
Reading and reporting of reviews and recent publications in biochemistry. Designed to be taken simultaneously with 7.68. *Robbins, Buchanan*

7.70 *Seminar in Protein Structure* (A)
Prereq.: 7.05
Year: G (1) 2–0–4
Reading and reporting of original papers on protein chemistry; group discussion of the experimental evidence for the chemical structure of proteins (for example, insulin, ribonuclease and hemoglobin); determination of the structure of some peptide hormones and their synthesis; the relationship between structure and function in some proteins. *Ingram*

7.77 *Biophysics Seminar* (A)
Prereq.: 7.06
Year: G (1) 1–0–2

7.78 *Biophysics Seminar* (A)
Prereq.: 7.06
Year: G (2) 1–0–2
Student presentation and discussion of reports on current literature in biophysics. *Levinthal*

7.81 *Enzymology* (A)
Prereq.: 7.05
Year: G (1) 2–0–4
Quantitative study of enzymes emphasizing their general properties; kinetics of reactions catalyzed by them; conditions which control their activity. *Sizer*

7.811 *Enzymology Laboratory* (A)
Prereq.: 7.81
Year: G (1) 0–4–2
Methods of purification of enzymes; determination of their catalytic activity and chemical properties; effects of environmental factors on enzymes. *Robbins*

7.85 *Optical Methods in Biophysics* (A)
Prereq.: 7.06, 8.04
Year: G (1) 2–2–4
Principles and biological applications of emission and absorption spectroscopy in the ultraviolet, visible, and X-ray regions; microscopy in general; electron microscopy; X-ray diffraction; related instrumentation. *Hall*

7.86 *Molecular Genetics* (A)
Prereq.: 7.06, 8.04
Year: G (2) 2–0–4
Recent experimental and theoretical developments in molecular genetics will be reviewed. Emphasis on the genetic, isotopic, and radiation experiments which yield information on the replication of nucleic acid, the mechanism of genetic recombination, and the translation of genetic information into molecular structure. *Levinthal*

7.90 *Seminar in Enzymology* (A)
Prereq.: 7.81
Year: G (2) 2–0–4
Discussion of recent advances in the field of enzymology, with emphasis on enzymes concerned with respiration, phosphorylation, and intermediary metabolism. *Sizer*

7.911 *Instrumentation and Research Methods* (A)
Prereq.: 8.04
Year: G (1) 2–0–4
Introductory subject in the analysis of physical research methods and instrumentation for the life sciences, including industrial biology and certain aspects of medical research. Principles of the basic instrumentation elements (primarily electrical elements). Preparation for synthesis and design of new research methods and systems for solution of biological problems. *Lion*

7.912 *Instrumentation and Research Methods Laboratory* (A)
Prereq.: 8.04
Year: G (1) 0–4–0
Laboratory subject, complementary to 7.911. *Lion*

7.92 *Electrical Instrumentation in Biology* (A)
Prereq.: 7.911, 7.912
Year: G (2) 0–4–0
Principles of electrical instrumentation in the biological sciences including research and industrial biology and certain aspects of medical science. Principles of electronics and electronic devices: amplifiers, oscillographs, photoelectric cells, X-ray tubes, and dosimeters. *Lion*

7.93 *Selected Topics in Biology* (A)
Prereq.: 7.05
Year: G (1 or 2) *Arr.*
Class work in various fields of biology not covered by the regular subjects of instruction. *Staff*

7.941 *Research Problems* (A)
Prereq.: ——
Year: G (1) *Arr.*
7.942 *Research Problems* (A)
Prereq.: ——
Year: G (2) *Arr.*
Directed research in a field of biological science, but not contributory to graduate thesis. *Staff*

7.95 *Electron Microscopy* (A)
Prereq.: 7.85 or 8.04
Year: G (2) 2–0–4
Principles of electron optics, the electron microscope, interaction of electrons with matter, methods in electron microscopy, applications of electron microscopy. *Hall*

7.96 *Electron Microscopy Laboratory* (A)
Prereq: 7.05
Year: G (2) 0–2–1
Properties of electron lenses, use of the electron microscope, preparation of specimens, techniques in electron microscopy, selected experiments. *Hall*

7.97 *Molecular Biology Seminar* (A)
Prereq.: 7.06
Year: G (1) 2–0–4
7.98 *Molecular Biology Seminar* (A)
Prereq.: 7.97
Year: G (2) 2–0–4
Molecular organization of cells and their products as revealed by electron microscopy, polarization optics, X-ray diffraction, physical chemistry, and cytochemistry. Fundamental structural and interaction properties of organized systems at different hierarchies of complexity, with particular emphasis on macromolecular, fibrous, and lamellar systems and their role in the physiology of the cell. *Schmitt, Davison*

7.99 *Molecular Configuration in Biological Systems Seminar* (A)
Prereq.: 7.06
Year: G (1) 2–0–4
The properties conferred on biochemical substances by assumption of specific physical configurations. Optical methods (emphasizing X-ray diffraction) for determining configuration in macromolecular systems. Selected examples of the relationship between molecular order and function in tissues. *Rich*

8.
Physics

8.00 *Physics*
Prereq.: ——
Year: G (S) 4–0–6
Specially arranged for Course XIII-A. ——

8.01 *Physics (Mechanics)*
Prereq.: ——
Year: 1 (1) 4–1–6
Particle mechanics including principles of conservation of mass-energy, momentum, energy and angular momentum. Oscillations, planetary motion, inertial forces. Elementary calculus used freely in the second half of the term. *Lazarus*

8.02 *Physics (Mechanics: Heat and Kinetic Theory, Waves)*
Prereq.: 8.01
Year: 1 (2) 4–1–6
Principles of rigid body motion. Properties of matter including elementary thermodynamics, kinetic theory of gases, solids, and liquids. Waves in matter. *Lazarus*

8.03 *Physics (Electricity and Magnetism)*
Prereq.: 8.02, 18.02
Year: U (1) 4–1–5
Fundamental laws of electricity and magnetism and some of their applications. Electrostatics, direct and alternating currents, magnetic fields, and induced electromotive forces. *H. Mueller*

8.031 *Physics (Electromagnetism)*
Prereq.: 8.02, 18.02
Year: U (1) 4–1–5
Fundamental laws of electricity and magnetism presented from the standpoint of field theory. Static and dynamic properties of the electromagnetic field, interaction of the field with charges and currents, dielectric and magnetic media, Maxwell's equations. *G. W. Clark*

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8.04 *Physics (Optics and Atomic Physics)*
Prereq.: 8.03
Year: U (2) 4–1–5
Propagation, reflection, refraction, interference, and diffraction of electromagnetic radiation. Introduction to the quantum aspect of electromagnetic waves and the wave aspect of particles. The sequence 8.03–8.04 is intended for those students who will terminate their study of physics at the end of their second year. *H. Mueller*

8.041 *Physics (Electromagnetic Theory of Light and Physical Optics)*
Prereq.: 8.031
Year: U (2) 4–1–5
Continuation of 8.031. Classical electromagnetic theory of light and its interaction with matter, Huygens' principle, physical optics. The sequence 8.031–8.041 is intended for those students who intend to continue the study of physics for at least one more semester. *G. W. Clark*

8.05 *Physics of Atoms and Molecules I*
Prereq.: 8.04 or 8.041
Year: U (1) 4–0–8
Survey of the experimental foundation of quantum physics with examples largely from atomic phenomena: optical, X-ray, radiofrequency, and infrared spectra; scattering of particles and radiation. Limitations of classical physics; photons, matter waves. Internal structure of atoms, and quantization; vector model, Pauli exclusion principle, and the periodic table of elements. *Pless*

8.051 *Introduction to Quantum Physics*
Prereq.: 8.04 or 8.041
Year: U (1, S) 4–0–5
Study of the experimental foundations of quantum physics and the quantum theoretical interpretation of atomic phenomena. *Whitney*

8.052 *Introduction to Solid-State and Molecular Physics*
Prereq.: 8.05 or 8.051
Year: U (2) 4–0–5
Elementary discussion of the quantum theory of molecules and solids. Nature of the molecular bond. Band theory of solids and its application to electrical conductivity, optical properties, and magnetism. *Whitney*

8.053 *Introduction to Nuclear Physics*
Prereq.: 8.051 or *8.06*
Year: U (2) 4–0–5
Discussion of various topics of nuclear physics with description of experiments and correlation of the results with current theories, such as two-nucleon systems, alpha and beta decay, gamma radiation, nuclear reactions, nuclear structure, and fission. *Enge*

8.055 *Elementary Nuclear Physics*
Prereq.: 8.051
Year: G (S) 4–0–5
Discussion of various topics of nuclear physics; description of experiments and correlation of the results with current theories. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*)

8.06 *Physics of Atoms and Molecules II*
Prereq.: 8.05
Year: U (2) 4–0–8
Continuation of 8.05. Introduction to quantum mechanics. Application of quantum mechanics to atomic and molecular phenomena. *Pless*

8.07 *Statistical Mechanics and Thermodynamics*
Prereq.: 8.05 or 8.051
Year: U (2) 4–0–6
Elementary kinetic theory and statistical mechanics, foundations of quantum statistics. Application to transport phenomena, heat capacities, black body radiation, electric and magnetic susceptibilities. Laws of thermodynamics with specific applications to the properties of matter. *Morse*

8.08 *Electronics*
Prereq.: 8.04 or 8.041
Year: U (1) 4–0–6
Electron ballistics, mass spectroscopy, introduction to theory of special relativity, principles of high-energy accelerators; space charge theory; Fermi-Dirac statistics, thermionic emission, Schottky effect, high field and secondary emission, photoelectric effect in metals, elementary properties of semiconductors. *Harvey*

8.09T *Experimental Atomic Physics I*
Prereq.: 8.04 or 8.041
Year: U (1) 0–6–6
Laboratory experiments on the foundations of modern physics: atomicity of matter and electricity, and special relativity. Typical experiments on Brownian motion, the Millikan oil drop method, charge-to-mass ratio of high-speed electrons, and Rutherford scattering. Opportunity for detailed technic·l training in use of machine tools, vacuum practice, glass blowing, and measurements of magnetic fields. *Valley*

8.10T *Experimental Atomic Physics II*
Prereq.: 8.05, 8.08, 8.09T
Year: U (2) 0–4–4
Continuation of 8.09: discreteness of atomic and molecular structure, and wave-corpuscle dualism. Typical experiments on studies of ammonia inversion line, absorption spectrum of sodium, X-ray emission spectra, diffraction of light, photoelectric effect, Zeeman effect, and cosmic ray telescope. Opportunity for detailed training in microwave electronics and pulse counting. *Valley*

8.11 *Experimental Physics and Thesis*
Prereq.: 8.10T
Year: U (1) 2–10–4
Introduction to experimental research techniques by (1) assigned laboratory exercises which include setting up and carrying through experiments concerned with fundamental principles in optics, nuclear, atomic, and molecular physics, or (2) participation in active research programs which may be part of senior thesis. Individual presentation of research projects to whole group. Designed to bridge gap between elementary laboratory and research in modern physics. *Osborne*

8.12 *Special Problems in Undergraduate Physics*
Prereq.: ——
Year: U (1, 2) *Arr.*
Opportunity for undergraduates to engage in experimental or theoretical research under the supervision of a staff member. *Staff*

ACOUSTICS

8.135 ***Special Problems in Acoustics*** **(A)**
Prereq.: 8.711
Year: G (1 or 2) *Arr.*
Advanced problems in acoustics or vibrations with assigned reading and consultation. *Staff*

OPTICS

8.18 ***Special Problems in Optics*** **(A)**
Prereq.: 8.04
Year: G (1 or 2) *Arr.*
Experimental work in the optics laboratory with assigned reading and consultation. *Staff*

ELECTRONICS

8.21 ***Physical Electronics*** **(A)**
Prereq.: 8.08
Year: G (1) 3–0–6
Introduction to theoretical and experimental aspects of physical electronics, including electron emission from solids (thermionic emission, photoelectric emission, secondary emission and strong-field emission), excitation of electrons in luminescent materials and other solids, excitation and ionization of gases by electrons, and gas discharge phenomena. *Nottingham*

8.212 ***Physical Electronics Laboratory*** **(A)**
Prereq.: 8.21
Year: G (2) 2–3–3
Lectures and laboratory for the development of techniques useful for research in physical electronics and their application to experimental investigation of important phenomena of physical electronics. *Nottingham*

8.231 ***Electrical Discharges in Gases*** **(A)**
Prereq.: 8.05, 8.07
Year: G (1) 3–0–6
Study of the fundamental processes of plasma physics, experimental determination of the basic cross sections, the calculation of electron and ion mobility and diffusion coefficients, the Townsend avalanche and breakdown, ambipolar diffusion and the positive column, statistics of energy gained by free electrons and its transfer to the excitation and ionization of atoms, the passage of radiation through an excited gas, space charge sheaths, probe theory and plasma diodes, time lags in breakdown, and the formation of a spark. *Allis*

8.232 ***Theory of Electrical Discharges in Gases*** **(A)**
Prereq.: 8.231, *8.72*
Year: G (2) 3–0–6
Theories relating to motions of electrons and ions in electric and magnetic fields. Particle orbits and adiabatic invariants. The Boltzmann equation and derivation of formulae for diffusion, mobility, and energy gain in d.c. and a.c. fields. The transport equation. Electromagnetic waves in a plasma. Space charge effects, including sheaths and plasma oscillations. Applications to highly ionized plasmas. (*Alternate years. Not offered 1961–62.*) *Allis*

8.25, 8.251 ***Special Problems in Electronics*** **(A)**
Prereq.: 8.08, *8.21*
Year: G (1 or 2) *Arr.*
Advanced problems in electronics, with assigned reading and consultation. *Staff*

X-RAYS AND CRYSTAL STRUCTURE

8.27 ***X-rays and Crystal Physics***
Prereq.: 8.05, 18.06
Year: G (1) 3–1–6
X-ray apparatus, production of X-rays, absorption, scattering, refraction, X-ray spectra. Theory and application of the diffraction of X-rays in matter to the determination of the structure of crystals, and the atomic and molecular arrangement in liquids and amorphous solids. General review of the structure of matter as determined by X-ray diffraction analysis. *Warren*

8.28 ***X-ray Diffraction*** **(A)**
Prereq.: 8.27
Year: G (2) 3–0–6
Selected advanced topics in the application of X-ray diffraction to problems of solid state physics. The elastic spectrum of crystals from the temperature diffuse scattering of X-rays. Measurement of long-range and short-range order parameters in binary alloys. Measurement of randomness in structures and cold work distortion in metals by X-ray diffraction. Fourier analysis of imperfect crystals. Discussion of extinction effects in perfect crystals. *Warren*

8.30 ***Special Problems in Crystal Physics*** **(A)**
Prereq.: 8.27
Year: G (1 or 2) *Arr.*
Advanced problems in X-ray diffraction or crystal physics with assigned reading and consultation. *Staff*

SPECTROSCOPY

8.321 ***Advanced Atomic Physics I*** **(A)**
Prereq.: 8.731
Year: G (1) 3–0–9
8.322 ***Advanced Atomic Physics II*** **(A)**
Prereq.: 8.321
Year: G (2) 3–0–9
Theory of spectroscopy, including atomic, molecular, and solid-state spectroscopy in optical and microwave regions, and atomic beams. Angular momentum through use of the Racah formalism. One-electron and many-electron atoms. Hyperfine structure. Radiation and observation of energy levels; analysis of experimental approaches. Molecular rotational, vibrational, and electronic energy levels. Atoms in crystal lattice; the Stark effect.

8.34, 8.341 ***Special Problems in Spectroscopy and Nuclear Magnetism*** **(A)**
Prereq.: 8.06
Year: G (1 or 2) *Arr.*
Advanced problems in the Spectroscopy Laboratory or in the Magnet Laboratory, with assigned reading and consultation. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

SOLID STATE AND STRUCTURE OF MATTER

8.361 *Quantum Theory of Matter I* (A)
Prereq.: 18.05
Year: G (1) 3–0–6
Principles of quantum mechanics with appiication to atomic structure. Schrödinger's equation, matrix methods, interaction of atoms and radiation. The hydrogen atom, the electron spin, angular momentum vectors and their interaction. The self-consistent field for atoms and the Hartree-Fock equation. Atomic multiplet theory. *Koster*

8.362 *Quantum Theory of Matter II* (A)
Prereq.: 8.361
Year: G (2) 3–0–6
Electronic structure of molecules and solids. The molecular orbital self-consistent-field method for molecules. General discussion of molecular binding. The energy-band theory of solids. Energy bands for metals, semiconductors, ionic crystals, molecular compounds. Relation of energy bands to electrical, optical, and magnetic properties of solids. *Slater*

8.363 *Selected Topics in the Theory of Solids I* (A)
Prereq.: 8.362
Year: G (1) 3–0–6

8.364 *Selected Topics in the Theory of Solids II* (A)
Prereq.: 8.363
Year: G (2) 3–0–6
Energy levels in solids: symmetry properties, electronic energy bands, nuclear vibrations, impurities, magnetic effects, crystalline field theory. Transport phenomena; selected topics varying from year to year. (*8.364 Alternate years.*) *Benedek*

8.37 *Neutron Diffraction* (A)
Prereq.: 3.50 or 8.27
Year: G (2) 3–1–6
Neutron properties, sources, and apparatus. Absorption and scattering of neutrons by isolated atoms. Transmission through and scattering by assemblages of atoms. Diffraction by single crystal and polycrystalline specimens. Crystallographic and magnetic structure analyses. Long wave-length methods and applications. Refractive index characteristics. Neutron polarization. Inelastic scattering. Laboratory experiments offered. (*Alternate years. Not offered 1961–62.*) *Shull*

8.38 *Special Problems in Neutron Diffraction* (A)
Prereq.: 8.37
Year: G (1 or 2) *Arr.*
Experimentation in solid state or neutron physics utilizing neutron scattering techniques. *Staff*

8.411 *Statistical Thermodynamics I* (A)
Prereq.: 8.731
Year: G (1) 3–0–9
Principles of thermodynamics. Conditions of equilibrium and stability. The thermodynamic potentials. Derivation of the thermodynamic formulae. Phase transitions of the first and second kind. Nernst's law. Statistical foundations. Ensembles. Canonical and microcanonical distributions. Fluctuations. Elementary quantum statistics, Boltzmann gas, Debye theory of specific heat, entropy constants. (*Alternate years.*) *Tisza*

8.412 *Statistical Thermodynamics II* (A)
Prereq.: 8.411
Year: G (2) 3–0–9
Fermi-Dirac and Bose-Einstein statistics. The adiabatic method, molecules. Periodic structures, lattice vibrations, electrons in periodic fields. Electric and magnetic properties of matter. Density matrix. Radial distribution function. Irreversible thermodynamics, microscopic reversibility, distribution of fluctuation paths. Transport and relaxation effects. Superfluids. (*Alternate years.*) *Tisza*

8.421 *Statistical Mechanics I* (A)
Prereq.: 8.731
Year: G (1) 4–0–8
Review of thermodynamics: First and Second Law. Thermodynamic potentials. Conditions for equilibrium. Phase transitions and other applications. Third Law. Classical kinetic theory of gases: method of collision.. Boltzmann H-Theorem. Maxwell-Boltzmann distribution. Transport phenomena. Hydrodynamics. Chapman-Enskog Method. Classical statistical mechanics: The microcanonical, canonical and grand canonical ensemble. Equivalence of ensembles. Relationship with thermodynamics. (*Alternate years. Not offered 1961–62.*) *Huang*

8.422 *Statistical Mechanics II* (A)
Prereq.: 8.421
Year: G (2) 4–0–8
Quantum statistical mechanics: Ensembles and density matrix. Darwin-Fowler method. Classical limit. Ideal gases and selected elementary applications in diamagnetism, paramagnetism, astrophysics. Bose-Einstein condensation. Imperfect gases. Virial expansion. Theory of equation of state and phase transitions. Special topics of application selected from theory of cooperative phenomena, quantum mechanical many-body problems. (*Alternate years. Not offered 1961–62.*) *Huang*

8.43 *Microwave Physics* (A)
Prereq.: 8.361 or 8.731
Year: G (2) 3–0–6
Theory and measurement of atomic, molecular, and crystal energy level differences corresponding to short-wave radio frequencies, with special emphasis on the paramagnetism of solids, liquids, and gases; time-dependent perturbations including induced absorption and thermal relaxation processes. Introduction to the experimental parameters defining the limits of experimentation; practical sensitivities and resolution. (*Alternate years. Not offered 1961–62.*) *Strandberg*

8.44 *Introduction to Solid-State Physics*
Prereq.: 8.05, 18.05
Year: U (1) 3–0–6
Introduction to property of solids, including classification, elastic constants, lattice vibrations, and thermal properties of solids: dielectric properties; paramagnetic, ferromagnetic, and antiferromagnetic states: superconductivity, conductivity, band theory of metals, properties of semiconductors, and imperfections in solids. Descriptive aspects of topics to be stressed since only elementary quantum mechanics to be used. *D. H. Douglass*

8.45 *Special Problems in Solid-State Physics* (A)
Prereq.: 8.362 or 8.412
Year: G (1 or 2) *Arr.*
Advanced problems in the physics of the solid state, with assigned reading and consultation. *Staff*

ELEMENTARY PARTICLES AND NUCLEAR PHYSICS

8.511 *Nuclear Physics I* (A)
Prereq.: 8.06, *8.711*
Year: G (1) 3–0–6
Advanced experimental nuclear physics, including description of the properties of nuclei and nuclear transformations, observational methods and instruments and correlation of experimental results with current theory. Charge, mass, radius, nuclear moments, statistics, parity, and selection rules for nuclear transitions. Interaction between particles, binding energy, nuclear models. Radioactive transformations, theory of statistics and fluctuations. *Grodzins*

8.512 *Nuclear Physics II* (A)
Prereq.: 8.511
Year: G (2) 3–0–6
Continuation of 8.511. Ionization, scattering, and radiative losses for swift-charged particles. Properties of neutrons. Origin of gamma rays and their interaction with matter. Transmutation; fission; reactions induced by charged particles, gamma rays, and neutrons; excitation functions. Artificial radioactivity, nuclear spectroscopy. *Grodzins*

8.531T *Nuclear Physics for Engineers I* (A)
Prereq.: 8.051 or 8.06
Year: G (1) 3–0–9
Nuclear phenomena, for advanced students not majoring in physics. Stationary states of nuclei: nuclear charge, radius, mass, moments, parity, and statistics. Barrier transmission; radioactive transitions; alpha, beta, and gamma decay. Binding energy, nuclear forces, and nuclear models. *R. D. Evans*

8.532T *Nuclear Physics for Engineers II* (A)
Prereq.: 8.531T
Year: G(2) 3–0–9
Continuation of 8.531. Nuclear dynamics: energetics and cross sections for nuclear reactions, scattering, and fission. Passage of charged particles through matter: ionization, scattering, and radiative losses. Interaction of neutrons and gamma rays with matter. *R. D. Evans*

8.541 *Introduction to Fundamental Particle Physics* (A)
Prereq.: 8.06
Year: G (1) 3–0–9
Observation and classification of elementary particles. Electromagnetic interactions of photons and charged particles. Classical and wave mechanics of collision and production processes. Conservation laws and invariance principles: charge, energy, momentum, angular momentum, parity, time reversal, isotopic spin, strangeness, baryonic and leptonic numbers. Strong interactions of mesons, nucleons, and hyperons. Weak interactions of leptons, mesons, nucleons, and hyperons. *Frisch*

8.542T *Meson Physics* (A)
Prereq.: 8.731
Year: G (2) 3–0–9
Scattering formalism for particles and photons with application to the analysis of decay interactions, polarization measurements, and resonance scattering. Study of meson-nucleon resonances and of electron-nucleon scattering. An unsophisticated approach to field theory to acquaint the student with "pololoogy" and dispersion relations as guides to experiments and data analysis. (*Alternate years. Not offered 1961–62.*) *Osborne*

8.543 *Strange Particle Physics* (A)
Prereq.: 8.732
Year: G (2) 3–0–9
Review of current status of K-meson and hyperon physics. Intensive analysis of selected topics such as the magnetic moments of the hyperons, the anisotropies in their decay modes, and photoproduction of K-mesons and hyperons. (*Alternate years.*) *Feld*

8.551 *Theory of Nuclear Structure I* (A)
Prereq.: 8.732
Year: G (1) 3–0–9
Review of the current theories of the structure of atomic nuclei. Nature of internuclear forces as determined by two-body phenomena. Discussion of three- and four-body problems. Nuclear spectroscopy. (*Alternate years. Not offered 1961–62.*) *Weisskopf*

8.552 *Theory of Nuclear Structure II* (A)
Prereq.: 8.551
Year: G (2) 3–0–9
Continuation of 8.551. Interaction of nuclei with light; beta decay; shell structure; theory of nuclear reactions; alpha decay. (*Alternate years. Not offered 1961–62.*) *Weisskopf*

8.56 *Cosmic Physics* (A)
Prereq.: 8.711, 8.72
Year: G (2) 3–0–6
Motions of charged particles in magnetic and electric fields. Properties of a plasma. Electromagnetic waves in a plasma and plasma waves. Acceleration mechanisms for charged particles. Applications to cosmic rays, geomagnetically trapped radiation, interplanetary plasma, and radioastronomy. (*Alternate years. Not offered 1961–62.*) *Rossi*

8.571 *Techniques of Experimental Physics I* (A)
Prereq: 6.14, 8.06
Year: G (1) 3–0–6
Intended to make the beginning graduate student familiar with some of the techniques of modern experimental physics, to show him what experimental physics is really like, and to acquaint him with some experimentalists in the department. Lectures by experts in each field, on such topics as magnetic and electrical measurements, fast and solid state electronics, magnet design, vacuum systems, low temperature techniques, optical systems, particle detectors (counters, emulsions, chambers), and data analysis (statistics and the use of computers). *Caldwell*

8.572 *Techniques of Experimental Physics II* (A)
Prereq.: 8.571
Year: G (2) 3–0–6
Survey of fields in which experimental research is currently carried on in the department, with particular emphasis on techniques used. Discussion by experts in each field of microwave, optical, and nuclear spectroscopy, molecular beams, magnetic resonance, X-ray and neutron diffraction, investigations of plasmas and the solid state, particle accelerators, and high energy and space experiments. *Caldwell*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

8.59 *Statistical Fluctuations in Physical Processes* (A)
Prereq.: 8.052 or 8.06
Year: G (2) 2–0–4
Application of statistical theory of fluctuations and errors to experimental physics. Theoretical frequency distributions: binomial, normal, Poisson, interval, and composite distributions. Statistical characterization of data, and tests of significance. Applications of Poisson statistics to the response of nuclear detection instruments, including scaling circuits and counting rate meters. Appraisal of random processes by inefficient statistics using nonparametric tests. *R. D. Evans*

8.60, 8.601 *Special Problems in Nuclear Physics* (A)
Prereq.: 8.511 or 8.531
Year: G (1 or 2) *Arr.*
Experimental work on radioactivity, nuclear bombardment, and general nuclear research, with assigned reading and consultation. *Staff*

8.61 *Special Problems in Elementary Particle Physics* (A)
Prereq.: 8.06, 8.09T
Year: G (1 or 2) *Arr.*
Experimental work on production, interaction, and decays of elementary particles, using a wide variety of electronic and visual techniques. Preparation and analysis of experiments carried out at the Cambridge Electron Accelerator, at Brookhaven accelerators, at Cosmic Ray stations, and in space probes. *Staff*

THEORETICAL PHYSICS

8.711 *Mechanics I* (A, except Course VIII)
Prereq.: 18.05
Year: U, G (1) 4–0–8
Mechanics of particles, planetary motion, scattering, rigid bodies, small vibrations, strings, membranes, acoustical and elastic waves. Lagrange's equations and generalized coordinates. *Ingard*

8.712 *Mechanics II* (A)
Prereq.: 8.711
Year: G (2) 4–0–8
Hamilton's equations, variational principles, transformation theory, Hamilton-Jacobi equation. Poisson and Lagrange brackets, invariants, conservation theorems, and symmetry. Lagrangian and Hamiltonian formulations for fields. Relativistic mechanics. *Ingard*

8.72 *Electromagnetic Radiation* (A, except Course VIII)
Prereq.: 18.05
Year: U, G (2) 4–0–8
Electrostatics and magnetostatics. Maxwell's equations, the potentials, Poynting's theorem. Plane waves in empty space, reflection and refraction. Wave guides and resonant cavities. Spherical waves, field of oscillating dipole. Radiation from antennas and antenna arrays and from atoms and molecules. Interference, diffraction, scattering. Electron theory of dielectric constant, permeability, and polarization. *Huang*

8.721 *Electromagnetic Theory I* (A)
Prereq.: 8.041, 18.05
Year: G (1) 4–0–8
Maxwell's equations; static approximation; scalar potential, multipole expansion; boundary value problem; polarization; stress tensor. Vector potential; fields and forces of steady currents; magnetization. Induction and displacement current; conservation laws, energy-momentum tensor. Waves, polarization, and coherence. Reflection, refraction, and scattering of waves; Huygens principle, geometrical optics. Multipole radiation, radiation damping, "Bremsstrahlung." *Lomon*

8.722 *Electromagnetic Theory II* (A)
Prereq.: 8.721
Year: G (2) 4–0–8
Classical electron theory. Vacuum field equations and equations of motion of electron. Lienard-Wiechert potentials. Self-energy and radiation damping. Derivation of macroscopic field equations; normal and anomalous dispersion. Zeeman effect. Special relativity. Covariant form of field equations and equations of motion. Potentials and gauge invariance. Green's function and causality. *Lomon*

8.731 *Introduction to Quantum Theory I* (A)
Prereq.: 8.06, 8.711, 8.72
Year: G (1) 3–0–9
Discussion of fundamental experiments. The quantum mechanical equations of motion. The harmonic oscillator, normal modes of radiation field. Transformation theory and its interpretation. The Schrödinger equation. Central field problems. Electron in a magnetic field. Zeeman effect and fine structure. Identical particles. *Villars*

8.732 *Introduction to Quantum Theory II* (A)
Prereq.: 8.731
Year: G (2) 3–0–9
Time dependence of operators and wave functions. Time dependent perturbation theory. Interaction of charged particles with electromagnetic field. Dipole and quadrupole radiation. Integral equation for scattering. Approximation methods. General scattering theory. Scattering of particles with spin, polarization. *Villars*

8.74 *Applications of Group Theory to Theoretical Physics* (A)
Prereq.: 8.361 or 8.731
Year: G (2) 3–0–6
Theory of groups and their matrix representations. Application to physical problems drawn from quantum and classical mechanics. Permutation groups and the Dirac Vector Model. Rotation and double groups. Space groups. (*Alternate years. Not offered 1961–62.*) *Koster*

8.75 *Operations Research, Principles and Applications* (A)
Prereq: 18.11
Year G (1) 3–3–6
Selected topics dealing with the application of experimental and theoretical techniques to the analysis of operational systems. Collection of operational data, use of machine simulation, determination of operating rules, and control criteria, illustrated by examples presented in the lectures and also by laboratory exercises.
Morse, Galliher, R. A. Howard

8.78 *Relativity* (A)
Prereq.: 8.722
Year: G (2) 3–0–9
Review of special relativity: Lorentz transformations, relativistic mechanics, and electromagnetism. The equivalence principle. Linear gravitational theories. General covariance. Elements of tensor analysis. The gravitational field equations and some special solutions. Gravitational waves, Mach's principle, and cosmological models. (*Alternate years.*) *Federbush*

8.791 ***Methods of Theoretical Physics I* (A)**
Prereq.: 8.711, 8.72
Year: G (1) 4–0–8
Solution of physical problems systematized by grouping them according to the partial differential equation they satisfy. Boundary conditions and methods of solution peculiar to each equation, including separation of variables, eigenfunctions, Green's function, integral equations, variational and perturbation procedures, integral representations, conformal transformations. Applications to problems in electrostatics, hydrodynamics, acoustics, quantum mechanics, et al. (*Alternate years.*) *Feshbach*

8.792 ***Methods of Theoretical Physics II* (A)**
Prereq.: 8.791
Year: G (2) 4–0–8
Continuation of 8.791, with emphasis on solutions for vector fields, electromagnetic fields, elasticity, etc. Special emphasis given, in alternate years, to either: (1) electromagnetic wave theory, including wave guide theory, radiation scattering and propagation of microwaves, etc.; or (2) relativity, including special relativity, relativistic dynamics with application to particle accelerators, selected topics in general relativity. (*Alternate years.*) *Feshbach*

8.861 ***Relativistic Quantum Mechanics I* (A)**
Prereq.: 8.732
Year: G (1) 3–0–9
Relativistic dynamics. The Klein-Gordon equation. π-mesic atom and Coulomb scattering of π-mesons. Relativistic Green's functions. The Dirac equation. The hydrogen-atom and scattering of electrons. Quantization of scalar, electromagnetic and spinor fields. (*Alternate years.*) *Schweber*

8.862 ***Relativistic Quantum Mechanics II* (A)**
Prereq.: 8.861
Year: G (2) 3–0–9
Spin and statistics. Theory of the scattering matrix. Feynman graphs. Compton effect, Møller scattering, and pair creation. Mass and charge renormalization, vacuum polarization. Radiative corrections to scattering and Lamb shift. Renormalization in Heisenberg representation. (*Alternate years.*) *Schweber*

8.90, 8.901 ***Special Problems in Theoretical Physics* (A)**
Prereq.: 8.791
Year: G (1 or 2) *Arr.*
Reading, consultation, and original investigation on a problem in theoretical physics. *Staff*

10.
Chemical Engineering

10.12 ***Chemical Engineering***
Prereq.: 5.02
Year: U (1) 3–0–5
Techniques of industrial chemical calculations. First law of thermodynamics and its application to chemical changes and to processes occurring in closed and open systems. *Merrill*

10.13 ***Chemical Engineering Thermodynamics***
Prereq.: 10.12, *18.04*
Year: U (2) 4–0–6
Second law of thermodynamics and its applications to compressors, pumps, refrigeration equipment, and to separation and other chemical engineering processes. Free energy and applications to chemical and phase equilibria. *Sherwood*

10.15 ***Thesis Reports***
Prereq.: ——
Year: U (1) 0–3–0
Work done in conjunction with the S.B. thesis. Written and oral reports on literature survey and experimental work. *C. J. King*

10.18 ***Industrial Chemistry***
Prereq.: 5.61, 10.31
Year: U (2) 3–0–6
Industrial chemical processes studied from the point of view of both the chemical reactions forming the basis of the process and the plant necessary for carrying on these reactions. Development of interrelationships of the different industries as to raw materials, sources of energy, and types of apparatus. Extensive problem work to be included. *Baddour*

10.21 ***Structure and Properties of Non-Metallic Substances***
Prereq.: 5.42, 5.62
Year: U (1) 3–0–6
Effect of intermolecular forces and molecular structure on physical properties of non-metallic substances. Subject matter similar in content to 10.63 but presented at a level commensurate with background of seniors majoring in chemical engineering. Emphasis on developing an approach based upon examination of phenomena, for solving problems in chemical processing. *Baddour*

10.25 ***Industrial Chemistry* (A)**
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
The technology of selected important chemical industries, with emphasis on applied physical chemistry and quantitative interrelationships; the economic significance of new developments. For new graduate students from other schools who have had insufficient training in the quantitative aspects of industrial chemistry. *Meissner*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

10.26 *Industrial Chemistry Laboratory*
Prereq.: 10.12
Year: U (1) 0–10–0
Laboratory practice in modern chemical technology, emphasizing the special features of *applied* chemical research, the application of engineering concepts, effective oral and written presentation of the research program, and safety practices. *G. C. Williams*

10.27 *Chemical Engineering Laboratory*
Prereq.: 10.31
Year: U (1) 0–10–0
Experimental studies of unit operations, with emphasis on momentum, heat, and mass transfer. Laboratory work on fluid flow, mixing, heat transfer, absorption, distillation, drying, filtration, and other unit operations, with particular attention to the dynamic response of such operations and proper instrumentation. *Vivian*

10.30 *Fluid Mechanics*
Prereq.: 10.12, *18.04*
Year: U (1) 4–0–6
Introduction to fluid mechanics. Dynamics of fluids in motion; laminar and turbulent flow; friction in conduits; application of Bernoulli equation; turbulent diffusion; transport of mass, heat, and momentum from a surface to a moving fluid. *Rosensweig*

10.31 *Chemical Engineering*
Prereq.: 10.30
Year: U (2) 4–0–6
Quantitative study of basic principles of the unit operations of chemical industry emphasizing material and energy balances, rate laws, and equilibrium considerations. Consideration of the following primary unit operations: heat transmission, evaporation, condensation, filtration, and agitation; emphasis on analogies between heat, mass, and momentum transfer. *Rosensweig*

10.32 *Chemical Engineering*
Prereq.: 10.30
Year: U (1) 4–0–6
Unit operations involving mass transfer and general diffusional theory as illustrated by absorption, adsorption, extraction, distillation, air conditioning, and drying; followed by comprehensive process design problems integrating all unit operations. *Mohr*

10.33 *Analytical Treatment of Chemical Engineering Processes* (A)
Prereq.: 5.62, 18.04
Year: G(2) 3–0–6
Mathematical techniques for handling rate problems such as diffusion, heat transfer, and chemical reaction which are basic to most chemical engineering operations. Training in setting up ordinary and partial differential equations corresponding to specific physical situations, and in methods available for their solution, including various graphical constructions. *Mickley*

10.34 *Numerical Solution of Problems in Chemical Engineering* (A)
Prereq.: 10.33
Year: G (1) 2–2–4
Advanced seminar in the numerical analysis associated with the solution of ordinary and especially partial differential equations by numerical methods. Lectures and problem assignments on the analysis of the stability and convergence of finite-difference methods of solving differential equations. Lectures and student seminar reports to cover recent advances and new techniques in the field. Each student to program and solve on the IBM 709 computer at least one problem from such fields as chemical reactor simulation, heat transfer, diffusion, and fluid mechanics, with the focus upon the relative effectiveness of various finite-difference methods of solving a particular type of problem. Some training in Fortran coding of the IBM 709. (*Limited to ten students. Permission of instructor required.*) *Brian*

10.35 *Dynamics and Control of Chemical Engineering Processes*
Prereq.: 10.31, 18.06
Year: U (2) 3–0–6
Description of the dynamic behavior of processes and equipment by ordinary and partial differential equations. Use of linearized approximations. Introduction to feedback control concepts. Solution of systems of equations by classical methods and by use of Laplace transforms. Use of approximation methods and analog computer solutions. Analysis of the stability of systems. Control system analysis and design. *Brian*

10.36T *Process Design*
Prereq.: 10.31
Year: U (1) 3–0–6
Presentation and discussion of real process design problems, with case studies in chemical processing and petrochemicals. Emphasis on conception and invention of processes, as well as analysis and economic balances, to specify optimum design and operating conditions. Discussion of a variety of cases throughout the term. *Sherwood*

10.37 *Chemical Kinetics*
Prereq.: 5.62, 10.30
Year: U (1) 3–0–6
Reactions of simple order and mechanism, with application to processes of industrial importance. Interaction of heat and mass transport with chemical reaction and application to simple design problems. (*Not offered 1961–62.*) *G. C. Williams*

ENGINEERING OPERATIONS

10.40 *Chemical Engineering Thermodynamics* (A)
Prereq.: 5.62, 10.13
Year: G (1, 2) 4–0–8
Properties of homogeneous and heterogeneous systems, physical and chemical equilibria and energy effects, and mechanical manipulation and control of industrial processes. Behavior of complex mixtures, correlation of data, and methods of approximation. *Reid*

10.41 *Distillation* (A)
Prereq.: 10.32
Year: G (1 or 2) 3–0–6
Basic principles of distillation as applied to binary and multi-component mixtures. Problems on vapor-liquid equilibria of ideal and non-ideal solutions, batch and continuous simple distillations, steam distillations, vacuum and pressure distillation, and rectification. Distillation of systems of limited miscibility; azeotropic distillation; extractive distillation; adsorption distillation. *Brian*

10.45 *Distillation and Absorption* (A)
Prereq.: 10.32
Year: G (1 or 2) 4–0–8
Distillation, including rectification of binary and complex mixtures. Diffusional processes, with attention to design computations for gas absorption equipment. A combination and condensation of subjects 10.41 and 10.46. *Vivian*

10.46 *Absorption and Extraction* (A)
Prereq.: 10.32
Year: G (1 or 2) 3–0–6
Basic principles of equilibria, mechanism, and rate of interaction. Quantitative applications including the absorption of single gases such as sulfur dioxide, ammonia, and hydrochloric acid and complex mixtures such as light oil, casing-head gasoline, refinery gases, etc. Graphical methods. Basic principles of extraction by liquids, solvent recovery by absorption and the leaching of various solids. *Sherwood*

10.47 *Ion Exchange* (A)
Prereq.: 5.62, 10.32
Year: G (2) 3–0–6
Preparation and properties of synthetic organic exchangers. Industrial applications of the general ion exchange process; equilibrium and rate studies for fixed and moving beds; ion exchange chromatography. *Baddour*

10.50 *Heat Transmission* (A)
Prereq.: 10.31
Year: G (1) 2–0–4
Application of fundamentals of conduction, radiation, and convection of heat to industrial problems. Numerical methods for complex problems in transient and steady onduct ion. Analogies between transfer of heat and momentum. Design problems, including economic balance between cost of heat-transfer surface and power.

10.52 *Chemical Engineering II* (A)
Prereq.: 10.32
Year: G (1) 3–0–6
Basic theories in flow of fluids and mass transfer. Application to problems of advanced character and attention to recent developments. *Fairbanks*

10.53 *Chemical Engineering Design* (A)
Prereq.: 10.31
Year: G (2) 3–0–6
Design of a complete plant. Plant size, location, and process used based on market analysis and technical and economic evaluation of alternative processes and of sources of raw materials. *G. C. Williams*

10.55 *Economic Balance in Chemical Industry* (A)
Prereq.: 10.31
Year: G (1 or 2) 3–0–6
Development of original power in the solution of problems in chemical industry covering a wide range of topics, with quantitative analysis of various factors under the control of the designer to determine optimum design from the viewpoint of cost and economic return. Economic balance applied to unit operations and to processes. (*Not offered 1961–62.*) *G. C. Williams*

APPLIED CHEMISTRY

10.60 *Catalysis*
Prereq.: 5.62
Year: U (1) 2–0–4
Methods of examining catalyst surface and structure. Physical adsorption, chemisorption; relationships between catalyst properties and activity. Catalysis mechanisms, evidence and theory. Mass-transfer controlling steps in catalysis. Case studies of several industrial catalysts. *Satterfield*

10.61J *Physics and Chemistry of Surfaces* (Same subject as 3.89J)
Prereq.: 5.62
Year: U (1) 3–0–6
Thermodynamic, structural, and kinetic factors underlying surface and interfacial phenomena. Molecular aspects of phase boundaries, intermolecular forces, and origins of surface tension. Capillarity and related phenomena. Thermodynamics of surfaces: surface activity, adsorption, and orientation at interfaces. Spreading, wetting, adhesion, and related processes. Electrical phenomena at interfaces: origins of surface potential, structure of the diffuse double layer, electrocapillarity. Survey of the importance of surface phenomena in processes such as flotation, detergency, corrosion, and catalysis. *Michaels, de Bruyn*

10.62 *Advanced Thermodynamics* (A)
Prereq.: 10.40
Year: G (2) 3–0–6
Further study of physical and chemical equilibria, particularly in heterogeneous systems. Special emphasis on prediction of thermodynamic properties by theoretical and empirical techniques. Consideration of the effects of surface and force field energies. *Meissner*

10.64 *Structure and Properties of Polymers* (A)
Prereq.: 5.42, 5.62
Year: G (2) 4–0–6
Effects of molecular structure (e.g., chain constitution, configuration, and conformation) of organic polymers on their mechanical, thermal, elastic, rheologic, and optical properties. Dependence of the properties of plastics, elastomers, and fibers on crystallinity, cross-linking, and the presence of fillers or plasticizers. Effect of polymer synthesis on structure, and of polymer structure on fabrication and utilization. *Michaels*

10.65 *Applied Chemical Kinetics* (A)
Prereq.: 5.62, *10.31*
Year: G (2) 3–0–6
Application of kinetics to development and improvement of industrial chemical processes. Basic concepts of homogeneous and heterogeneous reactions and of chain reactions. Interpretation of experimental data, determination of controlling steps in over-all rate, and choice and design of reactors. *Satterfield*

10.66 *Colloid Chemistry* (A)
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
The colloidal state of matter and the characteristics and behavior of colloids, natural colloids and different methods of producing matter in the colloidal state; methods used to study substances in the colloidal state. *Michaels*

10.67 *Applied Surface Chemistry* (A)
Prereq.: 10.21 or 10.63 or 10.66
Year: G (2) 3–0–6
Structure and properties of interfaces; functions and uses of surfactants; emulsification, foaming, detergency. Dispersion and flocculation mechanisms and their effects on sedimentation, filtration, suspension-rheology. Flow through porous media. Thermodynamics and kinetics of nucleation and crystal growth. Adhesion and adhesives. Application of surface phenomena to chemical process technology. *Michaels*

10.68 *Polymer Chemistry* (A)
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
Physical and chemical methods for characterizing the size and configuration of polymer molecules. Methods of synthesis of linear and network polymers; polymerization statistics and kinetics. Copolymerization techniques and analysis. Application of basic polymerization methods to the design and operation of industrial polymerization processes. *Michaels*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

10.69 ***High Polymer Technology*** **(A)**
Prereq.: 5.42, 5.62
Year: G (2) 3–0–6
Broad review of the chemical and engineering aspects of high polymer synthesis and manipulation. Physical methods of characterizing high polymers; basic chemistry and kinetics of polymerization reactions; industrial polymerization processes. Compounding and processing of resins and elastomers; molding, extrusion, and other polymer manipulation techniques. *Merrill*

10.70 ***Principles of Combustion*** **(A)**
Prereq.: ——
Year: G (1) 3–0–6
Application of the principles of chemical kinetics (including chain reactions) and of mixing and diffusion to combustion processes. Problems on rate processes in the combustion of gaseous, liquid, and solid fuels. Principles of model analysis. Thermodynamics of high-temperature processes, with applications to chemical processing and to high-output power plants such as turbines, rockets, ramjets. *Hottel*

10.72 ***Selected Combustion Problems*** **(A)**
Prereq.: ——
Year: G (2) 2–0–4
Seminar on advanced problems in combustion. Flame stabilization, simultaneous mass and heat transfer at phase interfaces where combustion occurs, flame propagation, mixing and mixedness, compressible flow, ignition, and combustion models. Sessions led by various staff members and research students. *G. C. Williams*

10.74 ***Radiative Transfer*** **(A)**
Prereq.: 10.31
Year: G (2) 3–0–6
Heat transmission in high-temperature operations. Radiation geometry; matrix algebra in application to radiative transfer in enclosures; zoning method as alternative to integral equation; use of machine computation. Thermal radiating characteristics of surfaces, gases, and particle clouds. Radiation methods of temperature measurement. Synthesis of analytical and empirical approach to produce approximations of engineering utility. Quantitative design of several furnaces and high-temperature systems. Interaction of radiative and other transport mechanisms. *Hottel*

SCHOOL OF CHEMICAL ENGINEERING PRACTICE

(See also 22.01–22.03 Engineering Practice School at Oak Ridge)

10.83 ***School of Chemical Engineering Practice — Bayway Station***
Prereq.: 10.32
Year: U (2) 0–18–0
Similar to 10.85. For seniors during the second period of the academic year. *Reid*

10.84 ***School of Chemical Engineering Practice — Bound Brook Station***
Prereq.: 10.32
Year: U (2) 0–18–0
Similar to 10.87. For seniors during the second period of the academic year. *Reid*

10.85 ***School of Chemical Engineering Practice — Bayway Station*** **(A)**
Prereq.: 10.32
Year: G (1 or 2) 0–12–0
Conducted in the refinery area of Esso Standard Oil Company, Linden, New Jersey: large scale production of gasoline, heating oils, tars, petrochemicals, and other petroleum products. Operations in all phases of petroleum refining and purification, including the manufacture of many petrochemicals. Problems in all phases of mass and heat transfer, kinetics, instrumentation, and other engineering operations. *Reid*

10.86 ***School of Chemical Engineering Practice — Bayway Station*** **(A)**
Prereq.: 10.85
Year: G (1 or 2) 0–12–0
Continuation of 10.85. *Reid*

10.87 ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.32
Year: G (1 or 2) 0–12–0
Conducted in the main plant of the Organic Chemicals Division of American Cyanamid Company at Bound Brook, New Jersey. Highly diversified operations, including process development and production of dyes, synthetic pharmaceuticals, organic pigments, rubber chemicals, intermediates, textile chemicals, plastics, resins, and related products. *Reid*

10.88 ***School of Chemical Engineering Practice — Bound Brook Station*** **(A)**
Prereq.: 10.87
Year: G (1 or 2) 0–12–0
Continuation of 10.87. *Reid*

GENERAL

10.90 ***Experimental Research Problem*** **(A)**
Prereq.: ——
Year: 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. *G. C. Williams*

10.91 ***Experimental Research Problem***
Prereq.: ——
Year: 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. *Baddour*

10.991 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (1) 2–0–4

10.992 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (2) 2–0–4
For students working on doctoral theses. *Gilliland*

12.
Geology and Geophysics

12.00 ***Earth Science (Geology, Geophysics, Geochemistry)***
Prereq.: ——
Year: 1 (2) 2–0–4
Lectures and demonstrations on the more important aspects of the origin, history, physical behavior and chemical constitution of the earth and the methods of reasoning and investigation by which the major concepts, laws and hypotheses of earth science were formulated. General topics to be discussed: earth origin and methods of determining sequence of events in geologic history; development of continents, oceans and mountains; evolution of plants and animals through geologic time; formation, distribution, and methods for discovery of minerals, rocks, ores, coal, petroleum and natural gas; reshaping of the earth's surface features by water, ice and wind; activities associated with earthquakes, volcanoes and hot springs; and discussion of the kinds of work carried on by earth scientists as geologists, geophysicists and geochemists. Local field trips to collect minerals and study features of bed rocks and glaciation. *Pinson*

12.001 ***Astronomy I***
Prereq.: ——
Year: 1 (1, 2) 3–0–3
Survey of the history of astronomy and its contributions in philosophy and science to our modern civilization. Emphasis on present theories of the age, origin, and evolution of the Universe. Lectures on the basic physical and chemical principles and the instruments used in modern astrophysics, followed by a study of the planets and their relation to the Universe. Discussion of concepts of stellar magnitudes, spectral classification, stellar energy production, galactic dynamics, Universe expansion, and element origin. Orientation of the Earth to the Universe. Several trips to Harvard Observatory and Agassiz Station. *Pinson*

12.002 ***Astronomy II***
Prereq.: 12.001
Year: U (1) 2–0–4
Survey of the history and basic data of astrophysics; review of atomic and molecular spectra applied to astrophysical problems; the spectral classification of the stars; interpretation of normal stellar spectra; stars with peculiar spectra; the physics of the stars; binary stars including eclipsing and spectrographic binaries; the intrinsic variable stars; the Fraunhofer spectrum; spectra of planetary atmospheres; interstellar matter. Opportunities for telescopic observations and visits to Harvard College Observatory and Agassiz Station. *Pinson*

12.003T ***Astronomy III***
Prereq.: 12.002
Year: U (2) 2–0–4
Some statistical data of astronomy; methods of measuring astronomical distances, centering about the establishment and reliability of the period — luminosity relationship; galactic clusters; globular clusters and population types; introduction to stellar evolution; structure, composition, and dynamics of the Milky Way; the Magellanic Clouds; and the revised time and distance scales of the Universe. *Pinson*

12.011 ***Mineralogy I***
Prereq.: 5.02
Year: U (1) 3–4–3
Study of the more common minerals, their crystal structure and crystal chemical relationships. Introduction to common rock types. Dennen, *Principles of Mineralogy.* *Dennen*

12.012 ***Mineralogy II***
Prereq.: 12.011
Year: U (2) 3–4–3
Intensive study of minerals with emphasis on determinative methods. Use and occurrence of minerals. Identification and classification of rocks. Dennen, *Principles of Mineralogy.* *Dennen*

12.05 ***Mineralogical Seminar* (A)**
Prereq.: 12.202
Year: G (1 or 2) 2–0–4
Presentation and discussion of literature bearing on certain phases of theoretical mineralogy. *Buerger*

12.14 ***Petrology***
Prereq.: 12.011, 12.301
Year: U (2) 2–0–4
Occurrence and origin of igneous and metamorphic rocks, with emphasis on correlation with experimental work. Turner and Verhoogen, *Igneous and Metamorphic Petrology.* *Fairbairn*

12.15 ***Petrology Laboratory***
Prereq.: 12.231
Year: U (2) 0–6–0
Use of the polarizing microscope on thin sections of igneous, metamorphic, and sedimentary rocks. Rogers and Kerr, *Optical Mineralogy;* Williams, Turner, Gilbert, *Petrography.* *Fairbairn*

12.161 ***Mineral Deposits and Petrology Seminar* (A)**
Prereq.: 12.14, 12.40
Year: G (1) 2–0–4

12.162 ***Mineral Deposits and Petrology Seminar* (A)**
Prereq.: 12.161
Year: G (2) 2–0–4
Discussion of igneous and metamorphic rocks, mineral deposits, and problems bearing on their genesis. (*Alternate years. Not offered 1961–62.*) *Hurley, Fairbairn*

12.17 ***Advanced Petrology Laboratory* (A)**
Prereq.: 12.15
Year: G (1) 0–4–2
Techniques of petrological research with applications of the Universal stage to mineralogical and petrofabric problems. Arranged to suit the requirements of individual students. *Fairbairn*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

12.201 ***Crystallography***
Prereq.: ——
Year: U (1) 2–2–2
Geometrical fundamentals of crystallography important in the study of mineralogy, metallography, chemistry, and solid-state physics. Symmetry and its restriction in crystals; crystal classes; crystal systems; crystal forms; methods of determining crystal symmetry; space groups; equipoints. Buerger, *Elementary Crystallography.* *Buerger*

12.202 ***Crystallography***
Prereq.: 12.201
Year: U (2) 2–0–4
Introduction to the theory of the structure of crystals, and application of crystal structure concepts to crystallography and mineralogy, including elementary crystal chemistry, structures of the silicates, polymorphism and transformations, disordered structures, solid solution and segregate phase formation, crystal growth and habit, crystal imperfection and lineage structure, and plastic deformation of crystals. *Buerger*

12.231 ***Optical Crystallography***
Prereq.: 12.011 or 12.201
Year: U (1) 0–6–2
Discussion of principles of optical crystallography, illustrated in the laboratory by the immersion method of crystal identification. Larsen and Berman, *Microscopic Determination of the Non-opaque Minerals* (U. S. G. S. Bull. 848); Wahlstrom, *Optical Crystallography.* *Fairbairn*

12.27 ***Crystallographic Research*** **(A)**
Prereq.: 12.201
Year: G (1 or 2) *Arr.*
Supervised research on a crystallographic problem. *Buerger*

12.301 ***Physical Geology***
Prereq.: ——
Year: U (1) 3–4–4
Objective study of the earth including geological agents and processes. Structural relations of rock masses. Laboratory and field exercises. *Dennen*

12.302 ***Historical Geology***
Prereq.: 12.301
Year: U (2) 3–4–4
Development of the surface features of the earth from the time of its origin to the present, including the nature and distribution of lands and seas during the past. Evolution of plants and animals. Principles and methods used in interpreting the geologic record of the past. Required field trip of six days during spring vacation. *Mencher*

12.304 ***Field Investigations and Reports***
Prereq.: 12.301
Year: U (S) 0–17–0
At Nova Scotia Centre for the Geological Sciences. Specific areas assigned to each group of students for survey and preparation of geological sections, maps, and reports. *Staff*

12.308 ***Sedimentation and Stratigraphy I***
Prereq.: 12.302
Year: U (1) 3–4–5

12.309 ***Sedimentation and Stratigraphy II***
Prereq.: 12.308
Year: U (2) 3–2–5
Principles leading to recognition of source, mode of transportation, and environment of deposition of sediments. Interrelationship of sedimentary and tectonic history of an area. Classification of sedimentary rocks. Sedimentary facies. (*Alternate years.*) *Mencher*

12.40 ***Mineral Deposits***
Prereq.: 12.011, 12.301
Year: U (1) 3–0–5
Occurrence and origin of ore deposits. Lindgren, *Mineral Deposits*, Fourth Edition. *Hurley*

12.41 ***Mineral Deposits Laboratory***
Prereq.: 12.301
Year: U (1) 0–4–0
Determination of ore minerals by microchemical analysis and by use of the metallographic microscope on polished sections; study of mineral relationships for interpretation of processes of deposition. Short, *Microscopic Determination of the Ore Minerals* (U.S.G.S. Bull. 914). *Hurley*

12.432 ***Advanced Mineral Deposits Laboratory*** **(A)**
Prereq.: 12.40
Year: G (2) 0–4–1
Study of specimens or suites of specimens from mineral deposits; metallographic or petrographic work. *Hurley*

12.441 ***Petroleum Geology I***
Prereq.: 12.302
Year: U (1) 3–0–5
Nature and origin of petroleum and natural gas. Factors responsible for accumulation of oil and gas. Principles underlying interpretation of oil field data. (*Alternate years. Not offered 1961–62.*) *Mencher*

12.442 ***Petroleum Geology II***
Prereq.: 12.441
Year: U (2) 3–0–5
Illustration of principles discussed in 12.441 by a study of typical oil fields. Applications to the location and evaluation of new fields. (*Alternate years. Not offered 1961–62.*) *Mencher*

12.45 ***Petroleum Geology Laboratory***
Prereq.: 12.441
Year: U (2) 0–6–2
Methods of illustration and interpretation of oil field data, in conjunction with principles discussed in 12.441. Study of well cuttings, cores, logs. *Mencher*

12.461 ***Petroleum Geology Seminar*** **(A)**
Prereq.: 12.441
Year: G (1) 2–0–6

12.462 ***Petroleum Geology Seminar*** **(A)**
Prereq.: 12.461
Year: G (2) 2–0–6
Discussion of latest information on origin, migration, and accumulation of petroleum. Evaluation of new methods of exploration for oil deposits. Stratigraphy and structure of principal oil-bearing areas of world. *Mencher*

12.51 *Paleontology*
Prereq.: 12.302
Year: U (1) 3–3–6
Study of the past plant and animal life of the earth through comparison of fossils with living plants and animals. Shrock and Twenhofel, *Principles of Invertebrate Paleontology.* (*Not offered 1961–62.*)

12.582 *Advanced Sedimentology* (A)
Prereq.: 12.581
Year: G (1 or 2) *Arr.*
Laboratory and microscopic study of the important primary and secondary physical, chemical and structural characteristics of sedimentary rocks using hand specimens, polished specimens and thin sections. Work arranged to suit the preparation and requirements of individual students. *Mencher*

12.583 *Sedimentology Seminar* (A)
Prereq.: 12.308
Year: G (2) 2–0–6
Discussion of latest literature on the origin, deposition, classification and significance of sediments and sedimentary rocks. *Shrock, Mencher*

12.60 *Oceanography I*
Prereq.: 5.02, 8.02, 18.02
Year: U (1 or 2) 3–0–6
Introduction to different aspects of the oceans and their relations to the atmosphere, solid earth, and marine life. Lectures varying from term to term and given by staff members from both M.I.T. and the Woods Hole Oceanographic Institution. *Staff*

12.611 *Chemical Oceanography I*
Prereq.: 5.02, 8.04
Year: U (1) 3–0–6
Study of the chemical systems in the oceans; the composition of sea water; the density-chlorinity-salinity relationships; the carbon dioxide system; the nutrient systems; dissolved gases; the routes and rates of material and energy transfer between hydrosphere, biosphere, and geosphere. Discussion of the methods of measurement of the dissolved substances in sea water. *Carritt*

12.612 *Seminar in Chemical Oceanography*
Prereq.: 12.611
Year: G (2) 3–0–6
Readings in the contemporary literature and discussion of several topics chosen to fit the backgrounds, fields of study, and interests of the participants. Topics in which chemical data are used in the interpretation of natural processes in the sea, such as carbon 14 dating in marine sediments in sea water; exchange of carbon dioxide (and other gases) across the sea surface; rates of physical, biological and geological processes in the oceans as inferred from chemical data; discussion of chemical species in natural fresh and salt waters. *Carritt*

12.65 *Special Problems*
Prereq.: ——
Year: U (1 or 2) *Arr.*
For seniors desiring special laboratory or field work on geologic problems. *Staff*

12.66 *Special Problems* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
For graduate students desiring special investigation of some geological subject or special laboratory or field work on geological problems. *Staff*

12.70 *Structural Geology*
Prereq.: 12.304
Year: U (1) 3–2–6
Elementary survey of rock structures and mechanics of rock deformation. Development of elementary concepts of plastic flow and fracture of materials. Within this framework, discussion of observed strains in all classes of rocks in relation to mineral deposits, intrusion and metamorphism. Laboratory work stressing map and rock interpretation and developing skill in three dimensional visualization. At least five Saturdays of field work near Boston mapping structures. *Staff*

12.72 *Mechanics of Rock Deformation I* (A)
Prereq.: 12.70, 18.06
Year: G (2) 3–0–9
12.73 *Mechanics of Rock Deformation II* (A)
Prereq.: 12.72
Year: G (2) 3–0–9
Cartesian tensors, problems of plane strain in elasticity and plasticity, finite homogeneous strain and its measurement in deformed rocks, dimensional analysis in its application to modeling properties of the crust of the earth. Survey of experimental rock deformation, theory of fracture as applied to faulting, crystal plasticity, thermodynamics of plasticity as applied to recrystallization in a stress field, plastic buckling. (*Not offered 1961–62.*) *Brace*

12.74 *Special Topics in Tectonics* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Advanced work in tectonics with time devoted to lectures, consultation, or assigned reading. Topics vary from year to year. (*Open only to properly qualified graduate students. Not offered 1961–62.*) *Brace*

12.801 *Theoretical Geology I* (A)
Prereq.: 8.041, 18.04
Year: G (1) 4–0–8
12.802 *Theoretical Geology II* (A)
Prereq.: 12.801
Year: G (2) 4–0–8
Applications of thermodynamics and statistical mechanics to geological problems and to the estimation of physical constants at depth in the earth. *Hughes*

12.811 *Geochemistry I* (A)
Prereq.: 5.61
Year: G (1) 3–0–6
Geochemistry of aqueous systems. A thorough review of mass action and calculations using thermodynamic data. Applications to carbonate equilibria, redox reactions, and other natural processes. *Winchester*

12.812 *Geochemistry II* (A)
Prereq.: 5.62, 12.811, 12.813
Year: G (2) 3–0–6
Selected topics in current geochemical research. Readings from the literature on the distribution of the elements and stable and radioactive isotopes, phase equilibria, kinetically controlled processes, and experimental methods in geochemistry. *Winchester*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

12.813 ***Nuclear Geochemistry*** **(A)**
Prereq.: 12.811
Year: G (2) 3–0–6
A review of basic concepts of atomic and nuclear physics, including radioactivity, nuclear reactions, and radiochemical methods. Application to experimental geochemistry, including activation analysis and the use of radiotracers, and to readioactive processes in nature, including the synthesis of elements in stars. *Winchester*

12.814 ***Geochemistry Laboratory*** **(A)**
Prereq.: 12.813
Year: G (1) 1–4–4
Laboratory work in experimental geochemistry, including use of x-ray diffraction and spectrography, activation analysis, and radiotracers. *Winchester*

12.818T ***Geochemistry Research Conference*** **(A)**
Prereq.: ——
Year: G (1) 1–0–0
12.819T ***Geochemistry Research Conference*** **(A)**
Prereq.: ——
Year: G (2) 1–0–0
Discussion of current research by graduate students and staff. *Winchester*

12.82 ***Spectrochemical Analysis*** **(A)**
Prereq.: 12.811
Year: G (1 or 2) 2–2–3
Elementary theory of spectroscopy. Excitation sources, particularly the D-C arc discharge. Qualitative and quantitative analysis with particular emphasis on the analysis of minerals, rocks and soils with the D-C arc. Ahrens, *Spectrochemical Analysis*. *Dennen*

12.831 ***Elements of Geophysics I***
Prereq.: 8.041, 18.04
Year: U (1) 3–0–9
Applications of potential theory to problems in gravity, magnetism, and steady electric current flow. Examples drawn from earth problems and from exploration geophysics. Inclusion of such topics as shape of the earth; isostasy; data collection, reduction, and interpretation.
Cantwell, Madden

12.832 ***Elements of Geophysics II***
Prereq.: 12.831
Year: U (2) 3–0–9
Study of elastic and electromagnetic wave propagation with applications to geophysics. Discussion of such topics as interpretation of deep earth structure, analysis of earthquake data, seismic wave propagation, seismic and electromagnetic prospecting problems, and treatment of earth's natural electromagnetic field.
Cantwell, Madden

12.833 ***Geophysical Laboratory***
Prereq.: 12.831
Year: U (2) 2–4–2
Experimental work in various phases of geophysics, including hydrodynamics, elasticity, and electromagnetism. Problems such as modelling, measurement of physical properties of materials, equipment design and construction, and field studies. *Cantwell, Greenewalt*

12.841 ***Geological Evolution of the Earth I***
Prereq.: 8.041, 18.04
Year: G (1) 3–0–6
12.842 ***Geological Evolution of the Earth II***
Prereq.: 12.841
Year: G (2) 3–0–6
Subject in general geology for graduate students entering geophysics from another field. Study of evolution of earth's interior, crust, oceans, and atmosphere. Structure of continents; genesis and distribution of crustal igneous rocks; history of major orogenic events and development of important thickness of sediments. Study of processes and events, with geophysical emphasis. *Hurley*

12.851 ***Geophysical Analysis and Computation*** **(A)**
Prereq.: 12.874, 18.06
Year: G (1) 2–1–6
12.852 ***Geophysical Analysis and Computation*** **(A)**
Prereq.: 12.851
Year: G (2) 2–1–6
Study of specific current geophysical problems to indicate where analytical treatment is no longer adequate and numerical procedures are necessary. Development and study of computational methods from the standpoint of high-speed computers. Presentation of reports on case studies by the students, covering both analytical and numerical work. (*Not offered 1961–62.*) *S. M. Simpson*

12.86 ***Elements of Seismology***
Prereq.: 18.04
Year: U (1) 2–0–4
Brief review of seismic elements; special elastic wave propagation problems of current interest; methods of treating random or quasi-random seismic data and propagation problems. *Staff*

12.873 ***Advanced Geophysics*** **(A)**
Prereq.: 12.832 or 18.15
Year: G (1) 3–0–6
12.874 ***Advanced Geophysics*** **(A)**
Prereq.: 12.873
Year: G (2) 3–0–6
Advanced topics in the analysis and interpretation of geophysical phenomena. Inclusion of such problems as potential fields and acoustic, elastic, and electromagnetic waves occurring in the earth and atmosphere.
Madden, S. M. Simpson

12.88 ***Geophysics Seminar*** **(A)**
Prereq.: 12.874
Year: G (1 or 2) 2–0–4
Problems of current geophysical interest; subject matter varying from term to term. *S. M. Simpson*

12.89 ***Isotope Geology*** **(A)**
Prereq.: 8.04, 12.301
Year: G (2) 2–0–4
Measurement and uses of the relative abundance of isotopes in geological materials; methods of measuring geological time, radioactive production of heat, and the quantity of radioactive elements in rocks and minerals, with demonstrations. *Hurley*

12.91 ***Mineral Industry I***
Prereq.: ——
Year: U (1) 3–0–6
Exploration and development of mines. Prospecting procedures and fundamentals of mining practice. Methods of production, management, organization, mining laws, health and safety. Field trips to properties which are in operation. *Parks*

12.92T *Mineral Industry II*
Prereq.: 12.91
Year: G (2) 3–0–6
Application of advanced techniques to mine planning, development and administration. Cost and productivity estimates. Case studies. Opportunity for mine inspection trips. *Parks*

12.94 *Mineral Economics*
Prereq.: ——
Year: U (1) 3–0–6
World mineral resources, their economic importance and industrial potential. Effects of distribution, control, monopolies, cartels, and tariffs on availability of mineral raw materials. Current mineral problems, national and international. *Parks*

12.95 *Valuation of Mineral Property* (A)
Prereq.: 12.92
Year: G (2) 3–0–6
Methods of examination and principles of valuation to equip the student with the theory of valuation and its practical application to representative types of mineral and oil property. Sampling, sampling calculations, estimation of ore, costs, selling prices, profit spread, the interest rate, depletion, and taxation. Parks, *Examination and Valuation of Mineral Property.* *Parks*

12.96 *Mineral Economics Seminar* (A)
Prereq.: 12.94
Year: G (1 or 2) *Arr.*
Detailed study or report on a particular mineral, area, or condition developing in the mineral field. *Parks*

12.97 *Mineral Valuation Seminar* (A)
Prereq : 12.95
Year: G (1 or 2) *Arr.*
Optional study; engineering report on valuation of a mineral or oil property, or detailed investigation of some phase of the problem, e.g., taxation. *Parks*

13.

Naval Architecture and Marine Engineering

13.00 *Principles of Naval Architecture*
Prereq.: 1.612 or 2.25
Year: U (1, 2) 4–1–7
Hydrostatics; buoyancy and stability of water-borne vehicles in intact, damaged, and partially water-borne conditions; dynamics and hydrodynamics applied to resistance, propulsion, and interaction effects of ships; equations of motion applied to controlled and uncontrolled motions of vessels in smooth and rough water. Laboratory exercises in the Ship Model Towing Tank and the Propeller Tunnel. *Abkowitz*

13.01 *Applied Hydrostatics* (R)
Prereq.: ——
Year: G (S) 1–7–2
Indoctrination lectures on elementary principles of naval ship design and statics of naval architecture. Work in the drawing room on 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 for a naval ship from preliminary design data. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Arentzen*

13.02 *Propulsion Hydrodynamics* (A)
Prereq.: 1.612 or 2.25; 13.00
Year: G (2) 3–0–6
Propulsion devices, particularly marine propellers; similitude and related selection parameters; interaction between propulsion and vehicle; momentum and energy considerations; extremals and optimization; rigorous development of fundamental airfoil theory in rectangular and cylindrical coordinates, and application to propeller design; special aspects of marine propulsive devices.
Powell

13.03 *Advanced Hydromechanics of Ship Design* (A)
Prereq.: 13.00
Year: G (2) 3–0–5
Advanced work in the application of theoretical and experimental hydrodynamics to the solution of marine vehicle design problems in the area of resistance, powering, steering, motion response, and control. Advanced considerations of motion stability and control and the behavior of uncontrolled and controlled ships in waves and rough seas. Discussion of modern model testing and computational techniques, and recent research and progress in marine vehicle hydrodynamics. *Abkowitz*

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13.10 ***Ship Structural Analysis and Design***
Prereq.: 2.01
Year: U (1) 3–3–6
General and local structural reactions of marine vehicles to their environment including consideration of materials, structural configurations, modes of failure, elastic and plastic instability, continuous frames, and plate theory. Integration and optimization of primary longitudinal structure. *J. H. Evans*

13.12 ***Naval Structural Theory I*** **(A)**
Prereq.: 2.046, 2.081
Year: G (1) 3–0–6
Discussion of structural loadings and reactions in naval vessels and the design integration of primary longitudinal hull structure. *J. H. Evans*

13.13 ***Naval Structural Theory II*** **(RA)**
Prereq.: 13.12
Year: G (2) 3–0–6
Selected topics of advanced structural analysis including sidesway in continuous frames, optimization of structural sections, web discontinuities, stiffened plates under lateral load, stiffened cylindrical shells, and ship oscillation loadings. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *J. H. Evans*

13.14 ***Naval Structural Design I*** **(RA)**
Prereq.: 13.12
Year: G (2) 0–5–0
Determination of load distribution on the hull of naval vessel types and development of optimized primary longitudinal structure. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *J. H. Evans*

13.15 ***Naval Structural Design II*** **(RA)**
Prereq.: 13.13
Year: (G) 1 0–5–0
Discussion and development of primary transverse structure such as bulkheads and ring frames for surface and submarine vehicles. Pressure vessel analysis and design. Discussion of structures under dynamic loadings due to air blast, underwater explosion, and pounding. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *J. H. Evans*

13.20 ***Energy Conversion Systems and Components***
Prereq.: 2.01, 2.403, *2.25*
Year: U (1) 4–1–7
Energy conversion devices and systems of types applicable to ships, involving thermal, mechanical, hydraulic, and electrical machinery; interaction of coupled devices under steady state and transient conditions; optimization principles. *Powell*

13.22 ***Naval Ship Propulsion I*** **(RA)**
Prereq.: 2.402, 2.501
Year: G (1) 3–2–6
Critical interpretation leading to useful application of the formal and theoretical content of naval engineering to foster discrimination in practice. Selection of machinery units, including propellers, supported by related design studies and calculations. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Baylis*

13.23 ***Naval Ship Propulsion II*** **(RA)**
Prereq.: 13.22
Year: G (2) 3–2–6
Continuation of 13.22, with emphasis on the complete propulsion plant rather than propulsion components. Influence of nuclear propulsion on plant cycles and arrangement. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Baylis*

13.24 ***Naval Electrical Engineering*** **(RA)**
Prereq.: 8.00, 18.07
Year: G (1, 2) 3–0–4
Review of basic electrical engineering, including single-phase and polyphase electric circuits, magnetic circuits and transformers, and electric machines. Critical examination of these electrical engineering principles as applied to the generation and distribution of electric energy in warships; system design; selection of machinery and equipment; the application of new developments in electrical engineering practice to warship electrical systems. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Baylis*

13.25 ***Advanced Naval Electrical Engineering*** **(RA)**
Prereq.: 6.03T
Year: G (2) 3–2–4
Critical examination of the principles of electrical engineering as applied to the generation and distribution of electric energy in warships on an advanced level; system design; selection of machinery and equipment in view of more recent developments in electrical engineering practice. Lectures, seminars, and outside reading. Design study of the generation and distribution system of a particular warship, including load analysis, distribution system layout, and selection of generating equipment. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Baylis*

13.30 ***Mechanical Vibration***
Prereq.: 2.02 or 2.046
Year: U (1, 2) 3–0–5
Dynamic problems of marine engineering. Elementary vibration theory, the balance of rotating and reciprocating machinery. Torsional vibration of reciprocating machinery, the vibration of turbines, and the vibration of ships. *F. M. Lewis*

13.31 ***Mechanical Vibration*** **(A)**
Prereq.: 2.046
Year: G (1) 3–0–6
Free and forced vibration of systems of a single degree of freedom; complex variable and vector representation; Fourier series; harmonic analysis by tabular and mechanical methods; systems of several degrees of freedom; torsional systems; balance of rotating machinery and reciprocating engines; elements of torsional vibration problems in reciprocating engines. *Den Hartog*

13.40 ***Introductory Ship Design***
Prereq.: 13.00, 13.10
Year: U (2) 1–6–2
Engineering and economic principles involved in the selection of dimensions and coefficients of commercial ships; design of hull form and internal arrangements and prediction of performance criteria in comprehensive design exercise. A condensation of material offered in 13.41 to satisfy departmental design requirement for undergraduate degree. *Mandel*

13.41 ***Principles of Ship Design*** **(A)**
Prereq.: 13.00; 13.10 or 13.12
Year: G (1) 2–4–5
Fundamental distinction among water-borne vehicles; engineering, economic, and military principles involved in the selection of dimensions and coefficients of displacement type commercial ships and warships; influence on dimension selection of rough water as well as smooth water considerations; design of hull form; internal arrangement design with emphasis on subdivision for survival after damage. Design exercises in application of principles. *Mandel*

13.42 *Preliminary Design of Ships* (A)
Prereq.: 13.41
Year: G (1, 2) *Arr.*
Preparation of the preliminary design of a water-borne vehicle selected by the student; emphasis on hydrodynamic, structural, or power plant aspects to suit interests of student. Fulfills department requirement of a comprehensive design problem for the Engineer degree. *Mandel, Powell*

13.43T *Naval Ship General Arrangements I* (R)
Prereq.: 13.01
Year: G (2) 3–0–5
Principles involved in the general arrangements of naval ships and in the design and installation of hull systems, fittings, and auxiliary machinery. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Arentzen*

13.44 *Naval Ship General Arrangements II* (R)
Prereq.: 13.00, 13.43T
Year: G (1) 0–5–0
Analyses of general arrangement problems; preparation of general arrangement plans. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Arentzen*

13.45 *Principles of Naval Ship Design* (RA)
Prereq.: 13.44
Year: G (1) 3–0–6
Fundamental considerations in selecting and providing the military features of naval ships. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Arentzen*

13.46 *Preliminary Design of Naval Ships* (RA)
Prereq.: 13.41, 13.45
Year: G (2) 0–9–3
Work in the drawing room, including the preparation of the necessary plans and calculations for the preliminary design of a naval ship. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Arentzen*

13.90 *Special Problems in Naval Architecture and Marine Engineering*
Prereq.: ——
Year: U (1, 2) *Arr.*
Special reading, study, design, and/or investigation under supervision of a specially qualified member of the faculty. Topics in naval architecture or marine engineering individually arranged to suit the interests of the student. (*Only for students with background in the field of naval architecture and marine engineering.*) *Powell*

13.91 *Special Problems in Naval Architecture and Marine Engineering* (A)
Prereq.: ——
Year: G (1, 2) *Arr*
Special reading, study, design, and/or investigation under supervision of a specially qualified member of the faculty. Topics in naval architecture or marine engineering individually arranged to suit the interests of the student. (*Only for students with background in the field of naval architecture and marine engineering.*) *Powell*

13.92 *Shipping Economics* (A)
Prereq.: 13.00, 13.20, *13.40*
Year: G (2) 3–0–9
Economic aspects of ship operation and design. Elementary principles of probability, statistics, and other operations research methods applied to marine transportation systems and components. Principles of optimization and applicable semi-analytical techniques. *Powell*

13.93 *Advanced Topics in Ship Design* (A)
Prereq.: 13.41
Year: G (2) 2–0–8
Seminars dealing with problems in naval architecture and ship design more advanced than those given in the undergraduate Course. Historical development, basic design of various types, structural design, stability in the damaged condition, subdivision, powering, analysis of performance, economics of design, general arrangements, cargo handling, launching, heating, ventilation, air conditioning, hull piping systems, etc. Discussion of naval and merchant vessels. *Arentzen*

13.94 *History of Naval Ships* (R)
Prereq.: ——
Year: G (1) 3–0–4
A seminar-type subject supplemented by lectures by members of the faculty and other authorities. Designed to give a perspective view of the characteristics of warships, including the interrelationships of such characteristics and the naval policies of the several powers, particularly the United States. Warship developments of World War II and possible developments of the future. (*Restricted to selected officers of the U. S. Navy and Coast Guard.*) *Arentzen*

13.95 *Hydroacoustics* (A)
Prereq.: 2.03 or 8.712 or 13.30; 18.06
Year: G (1) 3–0–6
Topics in underwater acoustics important to modern naval architecture and marine engineering. Physics of water; mechanism of cavitation; cavitation noise; cavity flows; jet and boundary layer noise. Radiation of sound by various types of sources. Transmission of sound in the ocean. Fundamentals of active and passive sonars. Vibrations in marine structures and machinery. Engineering applications to ship and submarine noise control. (*Primarily for graduate students in the Department of Naval Architecture and Marine Engineering; others should consult instructor.*) *D. Ross*

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14.
Economics and Social Science

GENERAL ECONOMICS AND THEORY

14.01 *Economic Principles I*
Prereq.: 21.02
Year: U (1, 2, S) 3–0–5
Introduction to fundamental economic concepts, such as production, money, banking, business organization, government fiscal policy, international trade, with emphasis upon the level and fluctuations in income, employment, and prices. Current economic problems. *E. C. Brown*

14.02 *Economic Principles II*
Prereq.: 14.01
Year: U (1, 2) 3–0–5
Continuation of 14.01. The composition and pricing of output of particular industries, supply and demand analysis and competition and monopoly. Current economic problems. *Adelman*

14.03 *Prices and Production*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
Basic theory of the equilibrium of the firm and the industry under conditions of competition, monopoly, and monopolistic competition; the consumption equilibrium of the household; factor markets and income distribution; introduction to concept of general equilibrium. *Bishop*

14.04 *Industrial Organization and Public Policy*
Prereq.: 14.02
Year: U (2) 3–0–5
Case studies of the economic organization of particular American industries, with evaluations of their efficiency and technological progressiveness; anti-trust laws and other regulations of business. *Fisher*

14.05 *Economic Fluctuations and Growth*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
Analytical study of determinants of national income level, employment, and prices; study of their fluctuations and long-run trends. Consideration of historical and current behavior of the economic system, and role of stabilization policies. *Ando*

14.06 *Structure of the American Economy*
Prereq.: 14.03
Year: U (2) 3–0–5
Study of magnitudes and quantitative relationships in the American economy having special relevance to an evaluation of the performance of the economy (its efficiency, growth, etc.), and to the design of public policy. Two or three special topics selected for detailed exploration; e.g., government expenditure, capital formation, industrial concentration, war-potential, labor force, income distribution, productivity, foreign trade. *Hagen*

14.07 *Comparative Economic Systems*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
Analytical study of economic problems under different economic systems such as capitalism and socialism; emphasis on economic problems of the Soviet Union. Role of the price system, investment decisions, monetary and fiscal policies, economic growth, etc. *Domar*

14.09 *Economic Problems Seminar*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
A seminar designed to complete a three-term humanities combination in economics and taking up selected problems of business and public policy, chosen because of their current interest or continuing significance for engineers and scientists. Development and application of the analytical techniques of 14.01 and 14.02. (*Sections limited to fifteen students.*) *Lefeber*

14.10T *Economic Growth and Development*
Prereq.: 14.02
Year: U (2) 3–0–5
Analytical treatment of the problems of economic growth and development combined with comparative studies of the growth of advanced and underdeveloped economies. Considerations of policy measures to promote economic development and growth. *Domar*

14.101 *Mathematics for Economists*
Prereq.: ——
Year: G (1) 3–0–6
Introduction to mathematical methods, with emphasis on topics useful in economics; differential calculus, problems in maxima and minima, functions of several variables. *Fisher*

14.102 *Mathematics for Economists*
Prereq.: 14.101
Year: G (2) 3–0–6
Continuation of 14.101. Elementary set operations, functions of several variables, integral calculus, Taylor series, elementary determinants and matrices. *Fisher*

14.11 *Linear and Nonlinear Programming*
Prereq.: 14.03; 18.15 or 18.20
Year: U (1) 3–0–5
Origin of linear programming problems. Properties of solutions. Simplex and other methods of computation. Duality and interpretation of the dual problem. Applications to firm, industry, and aggregate planning. Nonlinear programming. Discrete programming. Relations to general economic theory. *Solow*

14.114 *Economics and Finance: Principles and Policies I*
Prereq.: ——
Year: G (S) 4–0–9
Introductory discussion of the determination of national income and its fluctuations; the composition and pricing of output; financial institutions and the functioning of money and capital markets; fiscal and other stabilization policies; industrial economics, price policy and the relations of government and business; and international economics. (*Restricted to Sloan Fellows.*) *E. C. Brown*

14.115 *Economics and Finance: Principles and Policies II*
Prereq.: 14.114
Year: G (1) 3–0–6
Continuation of 14.114. (*Restricted to Sloan Fellows.*)
Rosenstein-Rodan

14.116 ***Economics and Finance: Principles and Policies III*** **(A)**
Prereq.: 14.115
Year: G (2) 3–0–6
Continuation of 14.115. (*Restricted to Sloan Fellows.*) *Adelman*

14.117 ***Economics and Industrial Management***
Prereq.: ——
Year: G (1, 2) 3–0–6
Introduction to measurement and determination of national income and national product; economic fluctuations and effectiveness of stabilization policies, especially monetary and fiscal. (*Restricted to graduate students in Course* XV.) *E. C. Brown*

14.121 ***Economic Analysis*** **(A)**
Prereq.: 14.03
Year: G (1) 3–0–6
14.122 ***Economic Analysis*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Interdependent growth of theory and fact, general theory of equilibrium under competition and monopoly. Findings revalued under conditions which more closely approach reality. *Samuelson*

14.123 ***Advanced Economic Theory*** **(A)**
Prereq.: 14.122
Year: G (1) 3–0–6
Continuation of 14.121 and 14.122 to cover more difficult aspects of material, together with still other branches of price and distribution theory and welfare economics. Content varying from year to year. *Samuelson, Fisher*

14.132 ***Schools of Economic Thought*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Economic ideas developed by different groups of economists in recent times. *Rosenstein-Rodan*

14.151 ***Mathematical Approach to Economics*** **(A)**
Prereq.: 14.122
Year: G (1) 3–0–6
The use of mathematical methods in all the fields of economics. *Samuelson*

14.161 ***Economic History*** **(A)**
Prereq.: 14.121
Year: G (1) 3–0–6
Analysis of development of world economy and major national economies in terms of theory of economic growth, 1750–1873. *Letwin*

14.162 ***Economic History*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Analysis of development of world economy and major national economies in terms of theory of economic growth, 1873 to present. *Letwin*

14.171 ***Theory of Economic Growth*** **(A)**
Prereq.: 14.122, 14.451
Year: G (1) 3–0–6
The interaction of economic variables in the long-run growth process. Theoretical models of the relationships among population and resource patterns, capital formation, monetization of the economy and growth of markets, technological change, sectoral patterns of investment, foreign trade, and the like. *Rosenstein-Rodan*

14.172 ***Research Seminar in Economic Development*** **(A)**
Prereq.: 14.171
Year: G (2) 3–0–6
Conceptual and empirical problems of conducting both library and field research on economic development. Discussion of formulation of relevant research topics, problems of quantification and measurement, interpretation of results, etc. Case materials from literature and from research in progress. *Millikan*

14.182 ***Capitalism, Socialism and Growth*** **(A)**
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6
A comparative study of capitalist and socialist economies mainly from the point of view of development and growth, and with major emphasis on the economy of the Soviet Union. *Domar*

14.191 ***Economics Seminar*** **(A)**
Prereq.: 14.121
Year: G (1) 3–0–6
14.192 ***Economics Seminar*** **(A)**
Prereq.: 14.121
Year: G (2) 3–0–6
Special economic problems. (*Open to graduate students only.*)

14.195 ***Reading Seminar in Economics*** **(A)**
Prereq.: 14.121
Year: G (1) *Arr.*
14.196 ***Reading Seminar in Economics*** **(A)**
Prereq.: 14.121 *Arr.*
Year: G (2)
Reading and discussion of special topics in economics. Open to advanced graduate students by arrangement with individual members of the staff.

INDUSTRIAL ECONOMICS

14.21 ***Economics of Innovation***
Prereq.: 14.02
Year: U (2) 3–0–5
Discussion of the process of research, invention and innovation in relation to economic development in the United States and other countries. (*Not offered 1961–62.*)

14.22 ***Economics of Particular Industries***
Prereq.: 14.03
Year: U (1, 2) 3–0–5
Analysis of key economic features of particular industries such as nature of production process, characteristics of demand for its output, financial problems, growth, stability, and location. Entire term ordinarily to be spent on two or three industries such as transportation, chemical, machinery, fuel and power, minerals, and retail. (*Not offered 1961–62.*) *Bishop*

14.23 ***Economics of Fuel and Power***
Prereq.: 14.02
Year: U (1) 3–0–6
Survey of the main trends in production, pricing, and investment costs of coal, electric power (hydro- and thermal electricity), crude oil, and refined oil products. Economics of nuclear power. An energy program for an underdeveloped country. Intended for students of either economics or engineering. *Rosenstein-Rodan*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

14.271 *Problems in Industrial Economics* (A)
Prereq.: 14.03
Year: G (1) 3–0–6
Small and large enterprises in the American economy; market structures; degrees of monopoly and competition; requisites of public policy. *Adelman*

14.272 *Government Regulation of Industry* (A)
Prereq.: 14.271
Year: G (2) 3–0–6
Follows 14.271. Development of anti-trust policy, generally and in specific cases. "Public utility" price fixing, government ownership as alternative. *Adelman*

14.281 *Entrepreneurship, Innovation and Economic Development* (A)
Prereq.: 14.03
Year: G (1) 3–0–6
The theory of innovation and its relation to capital formation; innovation and growth models; the impact of scientific research and technology; the clustering of innovations in relation to business cycles; measurement of innovation; classification of different types of industries; the role of the innovative and imitative entrepreneur in the economic development; difference in entrepreneurial types; contrasts and comparisons with entrepreneurship in selected countries in Europe and Asia. (*Not offered 1961–62.*)

14.282 *Economics of Innovation Seminar* (A)
Prereq.: 14.281
Year: G (2) 3–0–6
The theory and practice of industrial innovation; resistance to change; formulas for the measurement of resistance; methods of introducing innovations; classification of innovative types; sampling limitations; case studies of innovation in this country and abroad; innovative problems. Entrepreneurs in selected American industries invited to discuss the solutions offered. (*Not offered 1961–62.*)

14.291 *Industrial Economics Seminar* (A)
Prereq.: 14.271
Year: G (1) 3–0–6
14.292 *Industrial Economics Seminar* (A)
Prereq.: 14.271
Year: G (2) 3–0–6
Readings, discussions, reports on such topics as industrial price policies, government regulation of industry, competitive practices, and similar problems in industrial economics.

STATISTICS

14.31 *Elementary Statistical Analysis*
Prereq.: 18.04
Year: U (1) 3–0–5
Review of probability theory; multivariate distributions, sampling distributions, and limiting theorems; estimation; statistical decisions; regression analysis and analysis of variances. *Ando*

14.32 *Statistical Quality Control*
Prereq.: 14.31
Year: U (2) 3–0–6
Application of statistical methods to industrial problems including sampling inspection, quality control, and engineering tolerances. Duncan, *Quality Control and Industrial Statistics.* *H. A. Freeman*

14.371 *Statistical Theory* (A)
Prereq.: 18.04
Year: G (1) 3–0–6
Elementary but mathematical viewpoint. Random variables, elements of probability, mathematical expectation, generating functions, probability distributions, sampling theory, correlation and regression, elements of theories of estimation and testing hypothesis. *H. A. Freeman*

14.372 *Statistical Theory* (A)
Prereq.: 14.371
Year: G (2) 3–0–6
Maximum likelihood, the general linear hypothesis, Markoff theorem, stochastic processes, sequential analysis. *H. A. Freeman*

14.374 *Design and Analysis of Scientific Experiments* (A)
Prereq.: 14.371 or 18.10
Year: G (2) 3–0–6
Application of modern statistical theory to the design and analysis of scientific experiments. Discussion ranging from simple comparative experiments to experiments involving many factors and many variables, and centering on designs using analysis of variance. *H. A. Freeman*

14.381 *Statistical Method*
Prereq.: ——
Year: G (2) 3–0–6
Elements of probability, sampling, statistical inference, and the design and analysis of experiments, with emphasis on industrial applications and their interpretation, rather than on manipulation. *Solow*

14.383 *Econometrics* (A)
Prereq.: 14.102, 14.372
Year: G (1) 3–0–6
Principal statistical problems in the analysis of economic phenomena, including identification, least-squares bias, and autocorrelation, with emphasis on recent estimation procedures. Term project applying econometric techniques to economic phenomena required for each student. *Fisher*

14.384 *Advanced Topics in Econometrics* (A)
Prereq.: 14.383
Year: G (2) 3–0–6
Selected topics including specification error, non-linear estimation, simulation, aggregation, and the derivation of economic policy models. Term paper required. *Fisher, Ando*

14.39 *Economic Research Seminar*
Prereq.: 14.06, 14.31
Year: U (1) 2–0–6
Introduction to research procedures in economics in preparation for thesis. Students to prepare reports on research topics. *Domar, Ando*

14.391 *Research Seminar in Economics* (A)
Prereq.: 14.122, 14.452
Year: G (1, 2) 2–0–7
Individual or team participation in a single substantial project involving empirical or theoretical research with required report. Discussion of technical and statistical problems, as they arise. Varying topics from year to year. *Fisher, Solow*

NATIONAL INCOME AND FINANCE

14.40 *Monetary and Banking Policy*
Prereq.: 14.02
Year: U (2) 3–0–5
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, fiscal policy, international financial relations. *R. E. Freeman*

14.43 *Public Finance*
Prereq.: 14.02
Year: U (1) 3–0–5
Effects of government revenue and expenditure programs on the level and distribution of economic activity; intergovernmental fiscal problems; relationship of fiscal to other economic policies. *E. C. Brown*

14.451 *Theory of Income and Employment* (A)
Prereq.: 14.05
Year: G (1) 3–0–6
Examination of principal determinants of aggregate levels of income and employment. *Domar*

14.452 *Economic Growth and Fluctuations* (A)
Prereq.: 14.451
Year: G (2) 3–0–6
Application of theory of income and employment to analysis and measurement of changes in level of economic activity over time, and to study of inflation. *Solow*

14.461 *Monetary Economics* (A)
Prereq.: 14.451
Year: G (1) 3–0–6
Review of theory of income determination, with explicit attention to monetary parts of the model. Examination of sources and determinants of supply of money with attention to role of commercial banks, Federal Reserve System, and the Treasury. Exploration of both theory and facts about demand for money for transactions and for speculative purposes. Discussion of general equilibrium theory of money, interest, prices and output, and role of money in policy. *Ando*

14.471 *Fiscal Economics* (A)
Prereq.: 14.122, 14.452
Year: G (2) 3–0–6
Systematic examination of microeconomic and macroeconomic effects of particular governmental tax and expenditure programs. Treatment both theoretical and quantitative. *E. C. Brown*

14.472 *Seminar in Fiscal and Monetary Policy* (A)
Prereq.: 14.461 or 14.471
Year: G (2) 3–0–6
Analysis of economic effects of alternative governmental policies aimed towards stabilization and growth, economic development, and other social objectives. Various topics in these fields to be discussed from year to year. *E. C. Brown, Domar*

INTERNATIONAL ECONOMICS AND RELATIONS

14.51 *International Relations*
Prereq.: 21.04
Year: U (1, 2) 3–0–5
Basic factors in world politics: the influence of geography, demography, economic resources, nationalism upon national power and foreign relations. Power politics and the balance of power system. The formation and conduct of foreign policy. The United Nations and regional arrangements. The search for national and collective security *Padelford*

14.52 *Principles and Problems of American Diplomacy*
Prereq.: 14.51
Year: U (1, 2) 3–0–5
The underlying assumptions, basic principles and major objectives of American foreign policy. Some of the leading issues confronting American diplomacy today, including changing patterns of alignment, programs of economic and technical assistance, and domestic problems of policy making. *Russett*

14.521 *Strategic and Political Concepts*
Prereq.: 14.51
Year: G (1) 3–0–6
Geography as a basis of national economy. Geography of natural resources, including raw materials and sources of energy; their bearing on economic development and national security. Theories of utilization of land, sea, and air space. Global patterns and critical areas in politics and strategy. *Russett*

14.523 *National Security and Military Technology* (A)
Prereq.: 14.52 or 14.521
Year: G (1) 3–0–6
Analysis of major changes in science and technology affecting military capabilities, strategy and national security. Political implications of military technology; functional relationship between technology, military doctrine and foreign policy; problems which nuclear energy poses for national security. (*Not offered 1961–62.*)

14.524 *Politics and National Defense Policy* (A)
Prereq.: 14.52 or 14.521
Year: G (2) *Arr.*
Formulation and execution of national defense policy; the process which relates science, industry, the public, Congress and the Executive to the military in making decisions on national defense problems, including budgeting of national resources and use of manpower in war and peace. *Russett*

14.526 *Research and Development for Military Purposes*
Prereq.: ——
Year: G (2) 3–0–6
Management of military research and development in the U. S., including national policy and organization; the problem of ascertaining these relations among scientists, politicians, the military services, and industry that will best facilitate the generation of new ideas and the further development of military technology; case studies included. *A. G. Hill*

14.53 *Seminar in International Politics*
Prereq.: 14.52
Year: U (1) 3–0–5
Selected problems designed to complete a three-term sequence in international relations. Problems varying from year to year with special emphasis on the nations of Asia, Africa, and the Pacific area. *Padelford*

14.531 *Theory and Practice of International Relations* (A)
Prereq.: 14.53 or 14.98
Year: G (1) 3–0–6
The conceptual framework of international relations; analysis of theories seeking to structure a disciplinary and analytical approach; their relevance to actualities. Case studies in the decision-making process at the international level, involving especially the use of institutions and procedures of the United Nations, regional and specialized agencies on matters touching science and technology. *Padelford*

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14.532 ***Goals and Strategies in Foreign Affairs*** **(A)**
Prereq.: 14.51 or 14.531
Year: G (2) *Arr.*
Identification of foreign policy goals and interests, and the development of short- and long-term political doctrines and strategies. Factors in policy formulation — political, military, psychological, and technological — and the process of decision-making for foreign affairs. Illustrative problems of policy-making, and consideration of political gaming as a test for strategy. *Bloomfield*

14.534 ***The UN System and Problems of Political Development*** **(A)**
Prereq.: 14.51 or 14.531
Year: G (2) *Arr.*
The structure, process, and politics of international organizations, particularly within the UN system. Special emphasis on the role of international agencies in relation to political and economic development. Concepts of integration and community. Problems of collaboration with international institutions. *Bloomfield, Padelford*

14.535 ***U.S. Foreign Policy and Problems of Technological Change*** **(A)**
Prereq.: 14.51 or 14.532
Year: G (1) 3–0–6
Analysis of selected issues confronting U.S. foreign policy, with special emphasis on questions arising out of scientific and technological change, such as the problem of arms control and disarmament. *Bloomfield*

14.54 ***International Trade***
Prereq.: 14.01; 14.02 or 14.51
Year: U (2) 3–0–5
Theory of international trade and finance, and application to current problems, such as exchange restrictions, economic development, and foreign aid. *Lefeber*

14.57 ***Contemporary Ideas on Political and Economic Development***
Prereq.: Any two 14 or 21 subjects above 21.04
Year: U (1) 3–0–5
Evaluation of major political ideas from the 1890's to the present, with special attention to the problems that arise in their application to economic and political practice. Study of political ideas with regard to the actual performance by which they have been followed. The effects of ideas of liberalism on the actual extent of personal freedom. The effects of ideologies stressing economic growth on the course of economic development. The practices and institutions which conservative governments have been able to conserve in practice; and the extent to which the specific content of their conservatism has changed. Examination of the following political theories against a background of data from comparative politics and economic growth: the pragmatism and liberalism of John Dewey, William James, and J. M. Keynes; the pessimistic theories of Pareto and Spengler; Soviet Communism and "Titoism"; western economic planning and the welfare state; democratic socialism; Protestant and Catholic views of social reform; and current perspectives and trends in political and economic development. Particular emphasis in 1961–62 on contemporary systematic political theory. *K. W. Deutsch*

14.571 ***Major Problems in United States Foreign Policy***
Prereq.: ——
Year: G (2) 3–0–6
Analysis of some of the principal problems facing the United States in its present-day foreign relations. National security, relations with the Soviet Union, the North Atlantic Alliance, the Middle East, China, Africa, the U. N. (*Restricted to Sloan Fellows.*) *Padelford*

14.58 ***Nationalism and National Development***
Prereq.: Any two 14 or 21 subjects above 21.04
Year: G (2) 3–0–5
The interplay of political ideas and social institutions in the case of nationalism in the present era. Survey of ideas of nationality and contrast with the verifiable realities of peoples and countries. Effect of urbanization and industrialization on nationalism, and effect of nationalism on further political and economic development. Study of leaders and decisions against background of broad trends and particular movements. Survey of forces making for national sovereignty and contrast with trends toward federal government, economic unions, or international organization. *Tillman*

14.581 ***International Economics*** **(A)**
Prereq.: 14.03, 14.05
Year: G (1) 3–0–6

14.582 ***International Economics*** **(A)**
Prereq.: 14.581
Year: G (2) 3–0–6
The foreign exchange market, foreign trade and commercial policy, with emphasis on the relation of the items in the current account to national income: international finance and the achievement and maintenance of equilibrium in the balance of payments as a whole: current problems of international economics. *Kemp*

14.584 ***Seminar in International Economic Theory*** **(A)**
Prereq.: 14.582
Year: G (2) 2–0–7
Joint seminar meeting alternate weeks at Harvard and M.I.T., limited to second-year graduate students and beyond, including especially students preparing theses in international economics. Emphasis on theory, rather than empirical questions or policy issues, and on student contribution. *Kindleberger*

14.585 ***Elements of Economic Growth***
Prereq.: 14.901
Year: G (1) 3–0–6
Selected elements of income, employment, and price theory, followed by analysis of the interaction of economic variables in the process of economic growth of low-income economies. Introduction of technical economic concepts. (*Primarily for graduate students in political science.*) *Hagen*

14.59 ***Reading Seminar in Social Science***
Prereq.: ——
Year: 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. *Staff*

INDUSTRIAL RELATIONS

14.63 ***Labor Relations***
Prereq.: 21.04
Year: U (1, 2) 3–0–5
An introductory analysis, through an integrated social science approach, of the institutions which have developed in response to "human resource problems." The growth, structure, and objectives of management and organized labor groups, collective bargaining as part of a dynamic accommodation process between organizations that have economic, political, and social characteristics. *Siegel*

14.64 *Labor Economics and Public Policy*
Prereq.: 14.63
Year: U (1, 2) 3–0–5
Particular applications of the analytical tools developed in prerequisite subjects to two aspects of the industrial relations scene: (1) the economics of collective bargaining, problems presented by wage determination at firm, industry, and economy levels; and (2) the development of public policy on the rights and obligations of employers, unions, and workers. *R. Evans*

14.662 *Human Relations and Labor Relations*
Prereq.: ——
Year: G (S) 4–0–8
(1) The basic principles of human relations; (2) the place and functions of personnel administration, with emphasis on actual case situations; (3) the development of the American labor movement, significant union policies and practices, and basic issues raised by the present strength of unions. (*Restricted to Sloan Fellows.*) *Myers*

14.671 *Problems in Labor Economics* (A)
Prereq.: 14.64
Year: G (2) 3–0–6
Development of the labor movement, and detailed analysis of collective bargaining and union policies on wages, hours of work, entrance to the trade, hiring, layoffs and transfers, make-work and restriction of output, technological change, union-management cooperation, and industry-wide agreements. The economic aspects and effects of these policies. (*Not offered 1961–62.*) *Myers*

14.672 *Public Policy on Labor Relations* (A)
Prereq.: 14.64
Year: G (1 or 2) 3–0–6
Major trends in labor legislation, the legality of union activities, protection of the right to organize and bargain collectively, regulation of wages and hours, governmental machinery for the adjustment of labor disputes, and social insurance. The broad economic and social questions raised by these trends. *D. V. Brown*

14.673 *Labor-Management Relations and Public Policy* (A)
Prereq.: 14.662
Year: G (1) 3–0–6
Brief survey of the background of labor law, followed by analysis of the nature of the collective bargaining process, its major issues and points of contention. Discussion of selected problems in public policy. (*Restricted to Sloan Fellows.*) *D. V. Brown, Siegel*

14.674 *The Labor Movement: Theories and Histories* (A)
Prereq.: 14 64
Year: G (1) 3–0–6
Comparative analysis of labor organization in different contexts. 1. A review of traditional theories of the labor movement. 2. Examination of key labor problems common to industrialized or industrializing countries. 3. Historical analysis of labor organization in selected countries. *Siegel*

14.681 *Seminar in Personnel Administration* (A)
Prereq.: 14.63, 15.30
Year: G (1) 3–0–6

14.682 *Seminar in Personnel Administration* (A)
Prereq.: 14.681
Year: G (2) 3–0–6
Theory and practice of case study as dynamic learning. Experimentation with the "Incident Process" of case analysis. Demonstrations, followed by delegation of responsibility to the class for preparing and presenting case material and discussing these cases. Other objectives: learning to distinguish between facts and opinions, summarizing key facts, formulating issues, making and testing practical decisions, and generalizing from case situations. *Pigors*

14.69 *Labor Problems Seminar*
Prereq.: 14.64
Year: U (1 or 2) 3–0–5
Supplements the humanities combination in labor relations and labor economics. Selected labor problems chosen for their current interest or continuing significance. Development and application of problems and techniques of 14.63 and 14.64. (*Section limited to fifteen students.*) *Siegel*

14.691 *Research Seminar in Industrial Relations* (A)
Prereq.: 14.671 or 14.672
Year: G (1) 3–0–6
Discussion of important areas for research in industrial relations, frameworks for research, research techniques, and methodological problems. Centered mainly on the thesis research of advanced graduate students. *Myers*

14.692 *Research Seminar in Industrial Relations* (A)
Prereq.: 14.691
Year: G (2) 3–0–6
Continuation of 14.691. *Myers*

14.693 *Collective Bargaining and Union-Management Cooperation* (A)
Prereq.: 14.63
Year: G (2) 3–0–6
Intensive discussion of collective bargaining problems in particular industries and introduction to plans for union-management cooperation in solving production problems and reducing costs. *Lesieur*

PSYCHOLOGY AND SOCIOLOGY

14.70 *Introductory Psychology*
Prereq.: 21.02
Year: U (1, 2) 3–0–5
Discussion of facts, principles, and theories of development, motivation, learning, memory, thinking, emotion, personality, communication, intelligence, and social processes. *Howes, Swets*

14.73 *Organization and Communication in Groups*
Prereq.: 21.02
Year: U (1, 2) 3–0–5
This subject will deal with the problems in organization and communication in groups which have specific tasks to perform. Two-person situations, small informal groups, and larger organizations such as businesses, industrial firms, military units, etc., will be studied. The approach will be made from the point of view of social psychology. (*Not offered 1961–62.*)

14.75 *Experimental Psychology*
Prereq.: 14.70
Year: U (2) 3–0–5
Problems of method and procedure in the scientific study of living organisms. Analysis of and participation in psychological research. (*Not offered 1961–62.*)

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14.77 *Psychology of Language and Communication*
Prereq.: 14.70
Year: U (1) 3–0–5
Statistical and experimental studies of the psychology of language. The effects of verbal habits on perception, learning and communication. *Howes*

14.774 *Social Psychology Seminar* (A)
Prereq.: ——
Year: G (1) 3–0–6
Selected problems in social psychology; their origins and theoretical development; the methods and findings associated with them. *R. W. Brown*

14.79 *Learning*
Prereq.: 14.70
Year: U (2) 3–0–5
Experimental phenomena of conditioning and discrimination in various species. Analysis of complex learning, especially of verbal materials by human beings; memory and forgetting. Theories of learned behavior. *D. M. Green*

14.791 *Reading Seminar in Social Science* (A)
Prereq.: ——
Year: G (1) *Arr.*
14.792 *Reading Seminar in Social Science* (A)
Prereq.: ——
Year: G (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.

14.81 *Psychology of Perception*
Prereq.: 14.70
Year: U (1) 3–0–5
The basic sensory phenomena, with emphasis on vision and audition. Principles of perceptual organization. Classical and modern psychophysical methods and various theoretical analyses. *Swets*

14.82 *Psychology of Motivation*
Prereq.: 14.70
Year: U (1, 2) 3–0–5
Processes responsible for the activation of behavior patterns. Instinctive response patterns and their specific sensory releasers. Primary drives and related phenomena. Modern conceptualizations of motivation. Problems of maturation and species specificity in the analysis of these phenomena. *Melzack*

14.84 *Theories of Personality*
Prereq.: 14.70
Year: U (1, 2) 3–0–5
Survey of experimental methods for evaluating hypotheses drawn from personality theory and of some major findings derived from these methods. *Wallach*

14.85 *Social Psychology*
Prereq.: 14.70
Year: U (1) 3–0–5
Problems of social behavior; e.g., prejudices, rumor, riot, propaganda. Analysis in terms of basic principles of perception, learning, and motivation. *R. W. Brown*

14.86 *Behavior in Groups*
Prereq.: 14.70
Year: U (2) 3–0–5
Psychological study of the behavior of individuals in group situations. Field studies and laboratory research, with emphasis on the latter. *Schein, Bennis*

14.87 *Mass Communication*
Prereq.: 14.70
Year: U (2) 3–0–5
Crowd behavior, social movements, effects of mass media, prediction of voting. (*Not offered 1961–62.*) *R. W. Brown*

14.88 *Advanced Psychology Seminar*
Prereq.: 14.70 and any two subjects in psychology
Year: U (2) 3–0–5
Critical survey of contemporary problems in experimental psychology. Restricted enrollment. *Staff*

POLITICAL SCIENCE
(see also international economics)

14.901 *Concept Formation and Research Technique in Political Behavior*
Prereq.: ——
Year: G (1) *Arr.*
Requirements for testable concepts and innovations in research technique relating to attitudes, institutions, decision-making. Case studies on key problems of national, international, and comparative processes. *Lerner*

14.902 *Theory of Political Processes*
Prereq.: 14.901
Year: G (2) 3–0–6
Analysis of the theoretical assumptions underlying the political process at different levels and in different systems with a view to identifying structures and functions; representing these elements by suitable concepts or variables and examining their interrelationships in some scheme or model. Testing of different theoretical models by the insights they may yield about the same political practices or institutions as well as by their ability to bring out contrasts among different processes or types of government. *Pool*

14.903 *Introduction to Mathematical Models in the Social Sciences*
Prereq.: 14.901
Year: G (1) 3–0–6
Consideration in detail of three or four models in various areas of social science. Some drilling in the mathematics involved. Specially intended for people with little mathematical background. *Kramer*

14.91 *The American Political Process*
Prereq.: 21.02
Year: U (1, 2) 3–0–5
The functioning of the American political system under the impact of contemporary economic, social, and technological conditions. Particular attention is paid to the analysis of power on various levels of American society. *F. W. Frey, T. Harrison*

14.92 *Comparative Political Systems*
Prereq.: 21.04
Year: U (2) 3–0–5
Comparative study of the organization and use of political and economic power in contemporary foreign political systems, British and European parliamentary governments, the Soviet structure, and selected Asian institutions. Discussion of political parties and the changing role of government in society.

14.921 *Theories of Political Development* (A)
Prereq.: 14.52 or 14.901
Year: G (1) *Arr.*
Study of various 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. *Pye*

14.922 *Comparative Asian Politics* (A)
Prereq.: 14.901 or 14.921
Year: G (2) *Arr.*
Comparative analysis of political systems of Asia. Special attention to the processes of social change and the problem of political stability. Study will cover the transition from traditional and colonial systems to the contemporary ones. *Pye*

14.924 *Economic Development as Social Change* (A)
Prereq.: 14.121 or 14.901
Year: G (2) 3–0–6
Theory of social change, with the transition from traditional to technologically progressive society as the case to be studied. Presents a general system of theory, with personality, social, political, cultural, and economic-technical variables. *Hagen*

14.925 *Technological Progress and Political Behavior* (A)
Prereq.: 14.924
Year: G (1) 3–0–6
Theoretical introduction, then case studies of causal interrelations between technological progress and political organization and behavior in the early stages of industrialization. Will deal both with political organization as a factor influencing technological progress and with technological change as a factor causing change in political organization and behavior. (*Not offered 1961–62.*) *Hagen*

14.926 *The Communist Bloc* (A)
Prereq.: 14.901
Year: G (1) *Arr.*
The comparative study of the relationship of ideology and power in the development of the Communist systems of Russia, China, and Eastern Europe. Special attention to examination of the relative abilities of the various Communist movements to solve crucial problems in transferring traditional societies into modernized states. Discussion of such topics as the systematic examination of the traditional pre-Communist societies, the different efforts to translate Marxism into political movements, and the problems in organizing and managing social revolutions. *Pye, Griffith, Blackmer*

14.93 *Seminar: Issues in Contemporary American Politics*
Prereq.: 14.91 or 14.92
Year: U (1) 3–0–5
Selected problems connected with political parties, elections, and pressure politics; public policy in such fields as federalism, federal centralization, regional development, states rights; government and education; impact of national security problems on the Constitution and governmental institutions. Deals in 1961 with issues associated with American political parties. *Seasholes*

14.94 *Government, Politics and Technology*
Prereq.: 14.91 or 14.92
Year: U (2) 3–0–5
An examination of the impact of science on political ideologies and processes; the major public policy issues which technological advance poses for governments; the ways in which science modified patterns of political activity and institutions; the role of the scientist in political decision-making. Special emphasis on student projects which explore actual cases of political controversy involving technological change. *R. C. Wood*

14.941 *Government and Public Administration*
Prereq.: ——
Year: G (2) *Arr.*
Nature of public organizations and organizational behavior, with special emphasis on the role of the scientist and professional executive in the administrative process. Examination of major theories of bureaucracies and public administration, by reference to specific cases involving policy-making and execution, and the relation of elected and non-elected officials. *R. C. Wood*

14.942 *Metropolitanism, Federalism and Technological Change* (A)
Prereq.: 14.93 or 14.941
Year: G (1) *Arr.*
Study of the American federal system as it exists today, in the light of its adequacy in dealing with modern public problems and political trends. The strength of the system as a going political concern, its democratic characteristics, its influence upon the pattern of American politics, its effectiveness as an instrument of policy making, and its adjustment to the impact of technological change will be major topics of discussion. Particular emphasis will be given to the problems caused by the emergence of new metropolitan communities and to alternative systems of organizing government below the national level. *R. C. Wood*

14.943 *Politics and Outer Space* (A)
Prereq.: 14.53 or 14.941
Year: G (1) 3–0–6
Inquiry into some of the urgent problems posed by the opening of the Space Age for international relations, for government and society, and for the individual. Consideration of peaceful uses; economic impact; behavioral aspects; problems for public administration; and relevant issues of international politics, organization, and law. *Bloomfield*

14.944 *Scientific Development and Government Policy* (A)
Prereq.: 14.94 or 14.941
Year: G (2) 3–0–6
Organization of science for support of national policy. Place of science in government policy making for peaceful and military purposes. Emphasis on problems scientists face in relating research to governmental activities, and problems which critical role of scientists and technology raises for governmental policy makers. *Killian*

14.95 *Politics, Society, and Policy Making*
Prereq.: 14.01 or 14.51 or 14.91 or 21.42 or 21.43
Year: U (1) 3–0–5
Case material on decision-making examined with a view to seeing what types of persons are likely to take action and in what ways under a variety of conditions. Cases involve conflicts of parties, pressure groups and governmental policy makers in the U. S. Congress and in foreign decision-making bodies. *Pool*

14.951 *Changing Outlooks and Identities in World Affairs*
Prereq.: ——
Year: G (1) *Arr.*
Changes in human relations resulting from changes in power relations, new conceptions of others and of self arising, e.g., out of the end of colonial rule and the emergence of new national sovereignties in Asia and Africa; changes in national identities and in patterns of race attitudes and behavior; the consequences of the recession of white supremacy systems in Asia, the world, including the United States; problems of psychological re-tooling in the new modes of interaction among Americans, Europeans, Asians, and Africans. *Isaacs*

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14.953 ***Mass Media and Communication Systems***
Prereq.: ——
Year: G (2) *Arr.*
Examination of the pattern of communication in societies at different stages of development. Comparison of networks of oral communication with systems based on mass media. The role of opinion leaders, informal communication networks, literacy, the press, radio, film, and international communications. *Pool*

14.954 ***Methods of Communication Research*** **(A)**
Prereq.: 14.901
Year: G (2) 3–0–6
Survey analysis, content analysis, with some study of the institutional structure of communications and of communication flows. For students needing to secure or evaluate data about public opinion and attitude formation under the impact of communication. *F. W. Frey*

14.956 ***Public Opinion and Propaganda***
Prereq.: ——
Year: G (1) 3–0–6
History and development of public opinion as a factor in public policy: relationship of public opinion and private attitudes; organization of political parties and pressure groups; techniques used by them; conditions of effective and ineffective communications. *Pool*

14.957 ***Research Seminar in International Communications*** **(A)**
Prereq.: ——
Year: G (1) *Arr.*

14.958 ***Research Seminar in International Communications*** **(A)**
Prereq.: ——
Year: G (2) *Arr.*
Cooperative examination of key problems in this field. *Lerner*

14.96 ***Influences on Policy Decisions***
Prereq.: 14.95
Year: U (2) 3–0–5
Review of factors shaping such decisions as those examined in 14.95. Systematic analysis of communication flows, the values, motivations and personality traits of political activists, and the structure of power among them. Uses of game theory, operational codes, and elite analysis. (*Not offered 1961–62.*)

14.961 ***Personality, Society, and Politics***
Prereq.: 14.85
Year: G (1) *Arr.*
The gradual inclusion of the social environment in psychoanalytic theory. The psycho-sexual and psycho-social stages of man in their relation to social institutions. Personality in followership and in leadership. Application to selected political problems. (*Not offered 1961–62.*)

14.962 ***Identity and Ideology***
Prereq.: 21.04
Year: G (2) 3–0–6
Psycho-social and psycho-sexual problems of youth. Identity crisis and identity diffusion. Ideology as a transient necessity for individual maturation and for the rejuvenation of society. Application to political problems. (*Not offered 1961–62.*)

14.97 ***Political Science Seminar***
Prereq.: 14.52 or 14.57 or 14.93 or 14.96
Year: U (1) 3–0–5

14.98 ***Political Science Seminar***
Prereq.: 14.97
Year: U (2) 3–0–5
Seminar for students in political science program with members of the faculty to explore various aspects of selected problems in political science. Coordination of thinking from the varying points of view of political science and development of ability to deal with issues of decision-making. (*Not offered 1961–62.*)

14.99 ***Structure of Urban Life***
Prereq.: 14.91
Year: U (2) 2–4–10
Intensive survey of the political, economic and social systems in organized urban life today and the major public policy issues of urban regions, combining class and field work in a joint seminar with students from Dartmouth College. A weekly class meeting, in addition to an extensive coordinated field investigation of a highly urbanized area in Boston, employing the principal research techniques of social science. *R. C. Wood*

15.

Industrial Management

15.01 ***Industrial Management I***
Prereq.: 14.01
Year: U (2) 3–0–6
Economics of the firm and of the industry. How the price-profit system works through operation of supply and demand. Market structures and market behavior in specific industries. *S. S. Alexander*

15.02 ***Industrial Management II***
Prereq.: 18.04
Year: U (1) 3–0–6
Introduction to statistical methods with application to engineering and administrative problems. Basic statistical distributions including binomial, hypergeometric, Poisson, exponential, normal, and Chi-square. Introduction to acceptance sampling, quality control, and the analysis of variance. *Durand*

15.025 ***Statistical Method***
Prereq.: ——
Year: G (1) 3–0–6
Essentially the same material as 15.02; but at a slower rate and without going as deeply into mathematical derivations. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Durand*

15.03 ***Managerial Accounting and Controls for Engineers***
Prereq.: 14.01
Year: U (1, 2) 3–0–6
Survey of accounting concepts and procedures for control, managerial decision-making, and preparation of financial statements. Introduction to cost estimating, standard costs, and budgets. Emphasis on usefulness of accounting information to management in the control and evaluation of performance of projects, processes, and other segments of the firm. (*For students who plan no further course work in accounting. Course XV students not admitted.*) *Stedry*

15.032 *Sampling of Human Populations* (A)
Prereq.: 15.025 and consent of instructor
Year: G (2) 3–0–6
This subject is designed specifically for students in advanced marketing and demand analysis. Cluster sampling; equal and unequal sized cluster; cluster sampling with and without sub-sampling; multi-stage sampling; combinations of cluster sampling and stratified sampling; disproportionate stratified sampling; two-phased and sequential sampling. *Durand*

15.04 *Organization*
Prereq.: 15.01, 15.02; 15.03 or 15.50
Year: U (1, 2) 3–0–6
The organization as a system of people and institutions. Problems of leadership, morale, communication, control, and decision-making. *Haberstroh*

15.091 *Mathematics for Industrial Management: Elementary*
Prereq.: ——
Year: G (1) 3–0–6
Intended primarily for the entering graduate student whose mathematical background falls short of minimum requirements of the standard Master's program. Subject material not the same as the mathematics presented in statistics or production. Topics include important concepts of differential and integral calculus, elementary set theory, matrices and determinants, combinatorial mathematics, number systems, and difference equations. Emphasis on application to problems of management. (*Restricted to School of Industrial Management graduate students.*) *Emery*

15.11 *Introduction to Industrial Management*
Prereq.: 14.01
Year: U (1, 2) 3–0–6
Over-all view of managerial activities to develop interest in industrial administration. Not open to Courses XIV and XV. Basic treatment of fundamental principles and general practices of industrial management. Brief but specific coverage of selected important facets of marketing, finance, production, personnel, and administration. Relationship of scientist and engineer to functions and decisions of management. *L. B. Moore*

15.12 *Management Problems I*
Prereq.: 15.01, 15.02, 15.03
Year: U (1) 3–0–4
1st half: Introduction to managerial problems in marketing operations, with emphasis on the possibilities of gaining insight into the underlying determinants of consumer and industrial demand behavior through the medium of social and economic research. Basic policy considerations through which marketing management may adapt operations of a firm to changing market environment; selection and control of channels of distribution; product line, pricing, and sales promotion policy.
2d half: Quantitative approach to decision-making in production management. Incremental analysis, linear programming, stochastic models, waiting-line theory, and design of experiments with application to problems of economic quantities, production programming, statistical control, equipment purchase. *Hudgins*

15.13 *Management Problems II*
Prereq.: 15.01, 15.02, 15.03
Year: U (2) 3–0–4
1st half: Principles of financial organization and management; directed primarily toward analysis of demand for funds, internal and external supplies of funds, and their costs to the firm. Problems of internal financial control and techniques for their solution. Analysis of external supplies of funds dealing with corporate securities, marketing of securities, and structure of corporate capital and money markets. Consideration of effects of monetary policy upon supply of short- and long-term funds.
2d half: Integrated problems and cases demanding a balanced application of the principles and procedures covered in all subjects in the prescribed sequence. *Hudgins*

15.17 *Advanced Historical Studies* (A)
Prereq.: 15.201
Year: G (1, 2) 2–0–7
Opportunity for individual study with a staff member. Social and economic problems historically considered. Program determined by student and staff members to suit individual requirements; subject to approval of professor in charge. *Staff*

15.18 *Accounting and Production*
Prereq.: ——
Year: G (S) 5–0–10
A basic study of two important aspects of business management activity planned for students who have had substantial experience in industry: (1) basic methods and problems in maintaining financial and cost control records within a business and in the use of recorded data for policy determination and review of performance; (2) organization of manufacturing processes; emphasis on distinguishing fundamental principles from current practice. (*Restricted to Sloan Fellows.*) *Gordon, Goetz*

15.183 *Structure of American Law and Business Environment* (A)
Prereq.: 15.18
Year: G (1) 3–0–6
First half: study of fundamental legal principles as an element of the environment within which management of industrial enterprises is carried out. Second half: examination of major historical ideas affecting American industrial philosophies and processes. (*Restricted to Sloan Fellows.*) *Krebs, Morison*

15.185 *Management Problems* (A)
Prereq.: 15.18
Year: G (1) 3–0–6
Study of problems in two areas: (1) quantitative approaches to business problems and (2) marketing policy. Work at an advanced level for students who have had a substantial amount of general business experience. (*Restricted to Sloan Fellows.*) *Tallman, Goetz*

15.201 *Problems in American Political Economy*
Prereq.: ——
Year: G (1, 2) 3–0–6
Examination of economic, political and social problems developing from federal regulation of American economy. Emphasis on function of politics and law in reconciling conflicting demands of social groups. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Letwin, Travis*

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15.30 *Personnel Administration*
Prereq.: 14.01
Year: U (2) 3–0–6
Effective development and utilization of manpower. Personnel administration treated as staff function but line responsibility. Case method to help students develop a constructive personnel point of view. Organizational planning and executive development; recruitment, selection, placement and follow-up of employees; basic problem of worker's attitude toward authority; progressive discipline, industry as an economic and social system; management-union relationships, establishment and maintenance of satisfactory working conditions; job analysis and grading; wage and salary administration; interviewing and psychological tests as tools of management; employee participation in problems having to do with production. *Pigors*

15.312 *Labor-Management Relations*
Prereq.: ——
Year: G (2) 3–0–6
Structure and functioning of management and unions in handling of industrial relations; union policies; problems likely to arise. Reconciliation of union and management policies. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *D. V. Brown*

15.322 *Problems in Labor Relations and Personnel Administration* (A)
Prereq.: 15.312
Year: G (2) 3–0–6
The function of personnel administration and the role of the personnel administrator in the individual firm. Assumptions, objectives, and methodologies of the personnel function in several major problem and program areas. Field studies to examine company personnel programs. *Johnson*

15.362 *Seminar in Studies on Power and Authority in Organized Settings* (A)
Prereq.: 15.371
Year: G (2) 3–0–6
Analysis of elements in leadership and influence processes through use of concrete material drawn from various sources: research, novels, movies. Major part of subject centered on student's projects consisting of analysis of some variables examined in subject. (*Enrollment limited to 15 students. Admission by permission of instructor.*) (*Not offered 1961–62.*) *Bennis*

15.363 *Influence, Persuasion, and Attitude Change* (A)
Prereq.: 15.371
Year: G (1) 3–0–6
Seminar presenting some theoretical models of attitude change and examining their relevance for the influence of an organization on its members. Emphasis on gathering data and working up own projects. (*Enrollment limited to 15 students. Admission by permission of instructor.*) *Schein*

15.371 *Social Psychology*
Prereq.: ——
Year: G (1) 3–0–6
Opportunity for the student to become familiar with the methods, subject matter, and findings of social psychology, with opportunity to look into literature in the field and to raise questions about his reading. Detailed examination of a few subjects within social psychology which are particularly relevant to the problems of industrial management, with class discussions and reading on such subjects as motivation, learning and behavior change, leadership. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Marquis*

15.372 *Laboratory in Industrial Behavior* (A)
Prereq.: 14.662
Year: G (2) 3–0–6
Analysis — through lectures, discussions, and class exercises — of management of human resources in industry. Emphasis on internal relations of management. (*Restricted to Sloan Fellows.*) *Schein, McGregor*

15.373 *Seminar in Managerial Behavior* (A)
Prereq.: 15.371
Year: G (1) 2–0–7
Critical examination of manageriai policy and practice from the point of view of social psychology. Preliminary examination of the nature of the managerial task, followed by intensive study by each student of a specialized phase of the subject. (*Admission by permission of the instructor to students who have sufficient background for independent study in this field.*) *McGregor*

15.41 *Financial Management*
Prereq.: 15.03 or 15.50
Year: U (1, 2) 3–0–6
Principles of financial organization and management; directed primarily toward analysis of demand for funds, internal and external supplies of funds, and their costs to the firm. Problems of internal financial control and techniques for their solution. Analysis of external supplies of funds dealing with corporate securities, marketing of securities, and structure of corporate capital and money markets. Consideration of effects of monetary policy upon supply of short- and long-term funds. *E. Shapiro*

15.412T *Financial Management* (A) except XIV and XV)
Prereq.: 15.501
Year: G (2) 3–0–6
Analysis of the forces behind fluctuation of the size of short-term assets, and the effects upon short-term circuit flows of funds. Development of techniques of cash budgeting and liquidity analysis for planning and control of cash flow. Consideration of the determinants of long-term internal supplies of funds, including analysis of the effects of various depreciation schedules and of dividend and retention policies. Capital budgeting techniques for rationing funds among investment projects. Analysis of alternative security issues in resort to the capital market. Bank loan market. Effects of monetary policy upon the quantity and price of funds supplied to the corporate capital and money markets. (*Primarily for School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *E. Shapiro*

15.42 *Investments*
Prereq.: 15.02, 15.41
Year: U (2) 3–0–6
Formal analytical restatements of investment objectives and nature of alternative means for attaining these objectives; nature of investment risks and development of institutions for specialized risk taking: comparative advantage in investment and the returns for risk taking; industry and security analysis; security and commodity markets; emphasis on use of analytical and statistical techniques. *Cootner*

15.452 *Taxation and Business Management* (A)
Prereq.: 15.412
Year: G (2) 3–0–6
Influence of the tax structure on the decisions of management and the conduct of business enterprise. Situations where taxes directly impinge on the firm or where personal and business tax considerations are related to action pursued by the business firm. The relation between corporate and personal income taxes; tax treatment of capital gains; appropriate basis for and timing of depreciation charge; depletion allowances; pension, stock options, deferred compensation, and fringe benefits; other related topics. Sufficiently broad interpretation of the role and interests of management to include an examination of the effect of taxation on the level of investment and how it is financed. *D. M. Holland*

15.46 *Financial Administration of Industry* (A)
Prereq.: 15.412
Year: G (1) 3–0–6
Analysis of specific problems confronting business managers in internal financial management. Emphasis on current financial operations; problems of forecasting fund flows and alternative methods of financing future activity stressed. Financial problems relating to taxation; detailed examination of capital markets. Oral and written reports. *E. Shapiro*

15.50 *Managerial Accounting*
Prereq.: 14.01
Year: U (1, 2) 3–2–4
Introduction to basic concepts and techniques of financial reporting. Theory and methods of measurement of income and wealth. Justification and utility of accounting as a tool of applied economics with emphasis on its employment by management for control and decision-making. Investigations into the nature, generation, organization, analysis, and interpretations of data needed in evaluating and controlling the performance of the many activities of the individual business enterprise.
Gordon

15.501T *Managerial Accounting and Control*
Prereq.: ——
Year: G (1) 3–0–6
More intensive coverage of the topics embraced by 15.50. In addition, introduction to standard costs and their use for control and evaluation of performance. Nature of various types of costs, plans, and budgets, and techniques for their effective employment by management in improving efficiency. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Zannetos*

15.502 *Managerial Accounting*
Prereq.: 15.50
Year: G (1) 2–0–4
Introduction to the issues in the use of alternative bases of valuation in the measurement of income and wealth of a firm. Survey of the design and use of cost accounting systems to provide information for cost control and for evaluating alternative courses of action. (*Restricted to School of Industrial Management graduate students who have had previous work in accounting that is not equivalent to 15.501.*)
Zannetos

15.51 *Industrial Accounting and Control*
Prereq.: 15.50
Year: U (1, 2) 3–0–6
Analysis of information requirements of cost accounting systems. Study of cost and profit behavior within the firm. Problems of measuring costs and profits of individual products and activities of the firm. Methods of using accounting data in evaluating alternative courses of action, future planning, control of current operations. Case material from a variety of industrial situations supplemented by accounting exercises and selected readings. *Zannetos*

15.511 *Economics of the Firm*
Prereq.: ——
Year: G (1) 3–0–6
Economics of the firm and of the industry. How the price-profit system works through operation of supply and demand. Market structures and market behavior in specific industries. (*Restricted to School of Industrial Management graduate students; others admitted only with permission of instructor.*) *S. S. Alexander*

15.531 *Methods of Controllership* (A)
Prereq.: 15.501 or 15.502; 15.511
Year: G (1) 3–0–6
Design and use of semivariable overhead budgets and standard cost systems for determination of product costs for pricing and for planning and control of costs. Measurement of profit performance in decentralized companies. Cost analysis of alternative choice problems. Survey of other selected topics such as operations budgets, controllership functions, managerial implications of LIFO, and distribution cost analysis. Exercises, case material, and reports to develop facility in organizing and interpreting data. *Gordon*

15.542 *Management Information Systems* (A)
Prereq.: 15.03 or 15.501
Year: G (1, 2) 3–0–6
Study of the structure and related techniques of an information system required for managing an enterprise. Introduction to programming a stored program digital computer, automatic programming languages, data processing and data transmission equipment, and numerical analysis. Emphasis on the use of large-scale digital computers in integrated information and decision-making systems. Lectures, library research, problem formulation and solution, programming and operation of an IBM 1620 computer, and case studies of existing or proposed systems. *Emery*

15.58 *Industrial Dynamics*
Prereq.: 18.04
Year: U (1) 3–0–6
Treatment of management decision-making problems from over-all system point of view; primary emphasis on interaction of separate elements of an enterprise, examining flows of information, money, materials, manpower, and capital equipment. Study of behavior of firms and industries by computer simulation of feedback models representing organizational structure of firm and its basic policies and decision criteria. Application of system-dynamics approach to study of various current problem areas in industry, including inventory policies, ordering rules, cash flows, consumer behavior, hiring and firing policies, and R and D management. Application of principles of elementary feedback systems to industrial problems, providing experience with the use of digital computers for students' own models.
E. B. Roberts

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15.581 ***Industrial Dynamics I*** **(A)**
Prereq.: 18.04
Year: G (1) 3–0–6
Management decision-making treated from over-all system point of view; primary emphasis on interaction of separate elements of an enterprise. Effects of delays, smoothing, amplification, and noise on flow of information and material. Dynamic models of production-distribution systems simulated on a computer and their behavior studied. Background and application from current problem areas in industry. Subject matter drawn from theories of elementary feedback systems, difference equations, and probability; student should have basic abiiity in these subjects. Acquaintance with computing machines also desirable. Provision of experience with automatic programming for computer simulation; opportunity to run models on a machine.
E. B. Roberts

15.582 ***Industrial Dynamics II*** **(A)**
Prereq.: 15.58 or 15.581
Year: G (2) 3–0–6
Research seminar in business dynamics. Discussion of objectives of industrial dynamics, steps in a study, selection of a subject and definition of the problem within the context of an original industrial dynamics study. Development of a verbal dynamic model of the selected problem based on the literature and student experience. Conversion of the verbal model to a formal mathematical model. Simulation of the model. Interpretation of simulation results and revision of objectives and model. Redesign and improvement of the business system. Discussion of problems involved in implementing recommendations of the study. *Forrester*

15.59 ***Methods of Management Analysis***
Prereq.: 18.04
Year: G (1, 2) 3–0–6
Intended primarily for beginning graduate students in the doctoral or quantitative Master's program. Designed to provide a mathematical basis for the advanced subjects in management analysis. Selected treatment of linear algebra, set theory, convex sets, difference equations, Lagrange multipliers, variational methods, exponential smoothing, random number generation, feedback systems, and Markov chains. Examples drawn from current management problem areas. *Greenberger*

15.591 ***Management Analysis I: Inventory Control*** **(A)**
Prereq.: 14.371, 15.59
Year: G (1) 3–0–6
The function of inventory. Basic elements of inventory systems. Single and multi-item (depot, level, stage) models. Certainty and risk. Relevant costs. The forecasting problem. Moving averages and exponential smoothing. Linear decision rules for systematic planning of production, inventory, and work force. Continuous and periodic review. Application of waiting-line theory, Monte Carlo simulation, Markov processes, and feedback theory. Case studies. *Greenberger*

15.592 ***Management Analysis II: Mathematical Programming*** **(A)**
Prereq.: 14.371, 15.59
Year: G (2) 3–0–6
Linear programming, duality, parametric programming, integer programming, stochastic programming, nonlinear programming, network flow theory, dynamic programming, and calculus of variations. Applications to the scheduling of military research and development, warehousing, transportation, and equipment replacement. *S. F. Dreyfus*

15.593 ***Management Analysis III: Waiting-Line Theory*** **(A)**
Prereq.: 14.371, 15.59
Year: G (2) 3–0–6
Fundamental characteristics of waiting-line systems. Finite and infinite queues. Single and multiple servers. Poisson, Erlang, compound Poisson, and hyperexponential distributions. Stationary and nonstationary cases. Transient and steady state solutions. Priority procedures. Monte Carlo methods and simulation by computer. The imbedded Markov process, recursive calculation, and transform methods. Examples drawn from studies of communication systems, inventory control, machine assignment, maintenance, machine balancing, and traffic control. *Greenberger*

15.594J ***Systems Engineering and Operations Research*** **(A)**
(Same subject as 6.536J)
Prereq.: 6.27 or 18.10 or 18.18; 18.05
Year: G (2) 3–0–9
Analysis of linear probabilistic systems. Application of linear system theory to the study of finite- and infinite-state, discrete- and continuous-time, stationary and nonstationary Markov processes. Optimization of probabilistic systems over short and long time periods by means of dynamic programming. Consideration of digital computer simulations as supplements to analytical investigations. Concurrent presentation of examples in the areas of system reliability, congestion processes, maintenance and replacement policies, search procedures, inventory control, and other operating problems of systems. Discussion of unsolved problems and promising areas of research. *R. A. Howard*

15.599 ***Research Seminar in Management Analysis*** **(A)**
Prereq.: ——
Year: G (1, 2) 2–0–7
Student selects research project in management area making substantial use of statistics, computer simulation, or other quantitative methods of analysis. Project may be related to student's thesis. Careful review of the relevant literature, guest lectures, and general discussion on topics of special interest. (*Required subject for students electing the quantitative option in industrial management. May be elected by other graduate students upon consent of instructor.*) *Krebs*

15.61 ***Business Law***
Prereq.: 14.01
Year: U (1, 2) 3–0–6
Elementary study of some legal problems involved in the operation of a business enterprise; formation, performance and discharge of contracts, and remedies for breach, the Statute of Frauds; agency and employment relationships and liability of principal and agent in contract and tort; provisions of the Uniform Negotiable Instruments Act; use of checks, notes and other negotiable instruments; rights and duties of parties in various banking transactions; organization of corporations, duties and responsibilities of management, rights and remedies of stockholders and creditors; consideration of some legal aspects of corporate finance. *Macmillan*

15.65 ***Labor Law***
Prereq.: 14.01
Year: U (2) 3–0–6
Fundamental legal principles underlying formation and operation of labor unions, limitations upon right to strike and right of boycott, and control of union and employer activities by administrative governmental agencies. *Jacks*

15.66 *Fundamental Legal Principles* (A)
Prereq.: 15.312, 15.412, 15.712, 15.812
Year: G (2) 3–0–6
Survey of the fundamental principles of American law. Development of insights into capabilities and limitations of legal system, considered as an element of the environment within which management of industrial enterprises is carried out. The way in which the system works and changes, the underlying ethical and political ideas which give it direction, and the major policy issues exemplified in it. Seminar discussion of legal cases and selected essays. (*Admission limited to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Krebs*

15.71 *Production Management*
Prereq.: 15.02
Year: U (2) 3–0–6
Quantitative approach to decision-making in production management. Incremental analysis, linear programming, stochastic models, waiting-line theory, and design of experiments applied to problems of economic quantities, production programming, statistical control, equipment purchase. *Bowman, Goetz*

15.712 *Production Management*
Prereq.: 15.025, 15.511
Year: G (2) 3–0–6
Similar to 15.71. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Bowman*

15.72 *Industrial Standardization*
Prereq.: 14.01
Year: U (1) 3–0–6
Techniques of measurement and standardization and their relevance to data-gathering for decision-making. Standards as the basic requisite of any plan of control. Historical and theoretical background of standardization movement in industry. Standards for material: engineering standards and standards programs. Standards for manufacturing and office labor: evaluation of work measurement techniques, uses of time standards, discussion of relationship of time standards to wage payment plans. Standards for managerial and administrative performance: discussion of qualitative and quantitative methods of evaluation. Consideration of managerial uses of standards; emphasis on understanding the general techniques and the uses of standards rather than upon facility in using any of the specific techniques or methods. *Schreiber*

15.73 *Management Laboratory*
Prereq.: 14.01
Year: U (1, 2) 3–3–3
Psychology and methodology of industrial improvement. Work simplification. Techniques of improvement including motion economy, work space and plant layout, process charts, flow diagrams, and other current practices as utilized in measurement and analysis of work cycles. Economic and psychological theory of the improvement process. Problems in management creativity. Laboratory experimentation. Participation in an actual company project situation. *Goodwin*

15.74 *Advanced Management Laboratory*
Prereq.: 15.73
Year: U (2) 3–3–3
Organization and implementation of industrial improvement. Advanced treatment of work simplification. Managerial procedures employed in introducing and developing a company improvement program with administrators, executives, and employees. Appreciation, educational, and application phases of the company program. Coordination of all improvement activities within the company. Laboratory experimentation with and personal involvement in an actual company program situation. *Goodwin*

15.741 *Advanced Management Laboratory* (A)
Prereq.: 15.712
Year: G (1) 3–3–3
Industrial improvement as a management philosophy. Coordination of methods of analysis, design, measurement, and control of physical activity. Critical analysis and appraisal of various improvement techniques and methods of implementing production improvements in industry. Laboratory and field experimentation. Involvement in actual industrial situations. *Schreiber, Goodwin*

15.75 *Manufacturing Analysis*
Prereq.: 15.71
Year: U (1) 3–0–6
Field applications of methods of analysis developed in 15.71. Development of actual data required for operational use of decision-making models. *Goetz*

15.751 *Manufacturing Analysis* (A)
Prereq.: 15.712
Year: G (1) 3–0–6
Subject matter of 15.75 at advanced level. *Goetz*

15.78 *Studies in Manufacturing Analysis*
Prereq.: 15.71
Year: U (1) 3–0–6
Examination of studies from current literature devoted to formal methods for analyzing production management problems. Applications of linear programming, other programming applications, waiting line applications, applications of incremental analysis, and total cost and value models presented from the empirical literatures of management science, operations research, economics, and statistics. Student seminar responsibilities. *Bowman*

15.781 *Studies in Manufacturing Analysis* (A)
Prereq.: 15.712
Year: G (1) 4–0–5
Examination of studies from current literature devoted to formal methods for analyzing production management problems. General readings bearing on each method of analysis also included. Analysis of case studies as time permits. *Bowman*

15.791 *Operational Models of the Firm* (A)
Prereq.: 15.501, 15.511, 15.712, 18.04
Year: G (1) 3–0–6
Intensive analyses of selected kinds of management decision problems that involve interrelationships among functional areas. Study and solution of decision problems of rather broad scope by use of mathematical and statistical methods such as differential and difference equations, transform theory, calculus of variations, signal flow analysis, and Markov processes. Relation of theory and practice. Design of efficient operating techniques based upon theoretical findings. Student participation in field studies and special projects. *Maffei*

15.792 *Manufacturing Decisions Seminar* (A)
Prereq.: 15.712
Year: G (2) 3–0–6
Seminar based on literature of decision making and one manufacturing problem area, such as inventory, scheduling, quality, or equipment, combined with field study in a local firm to observe, describe, and predict the decision-making behavior of individuals concerning that manufacturing problem. *Bowman*

15.81 *Marketing*
Prereq.: 15.01
Year: U (1, 2) 3–0–6
Introduction to managerial problems in marketing operations, emphasizing possibilities of gaining insight

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into the underlying determinants and dynamics of consumer and industrial demand behavior through the medium of social and economic research. Basic policy considerations through which marketing management may adapt operations of firm to changing market environment: selection and control of channels of distribution, product line, pricing, and sales promotion policy. Theoretical concepts and quantitative techniques applied in study of marketing phenomena. *Claycamp*

15.812 *Marketing*
Prereq.: ——
Year: G (2) 4–0–5
Intensive coverage of the same subject areas as 15.81, with addition of a seminar involving oral reports and group discussions of topics selected by individual class members. (*Restricted to School of Industrial Management graduate students; others admitted only by permission of the instructor.*) *Tallman*

15.82 *Marketing Management*
Prereq.: 15.81
Year: U (2) 3–0–6
An advanced subject rounding out and building upon material studied in 15.81. Focus on the decision-making process in marketing management. Intensive attention given to opportunities for, and means of, sales development through advertising, sales force, and other promotional means. The perspective of developing and appraising total marketing strategy maintained with product development, pricing, and distribution considered along with the study of promotional activities. Selected readings and case materials to provide background for team participation and individual exercises based upon a large-scale computerized marketing game. *Massy*

15.821 *Marketing Policy and Administration* (A)
Prereq.: 15.812
Year: G (1) 3–0–6
Intensive treatment of subject area of 15.82. Selected readings and case discussions to provide background for team participation in a large-scale computerized marketing game. Seminar, with student presentation of oral reports. *Massy*

15.83 *Marketing Research*
Prereq.: 15.81
Year: U (1) 3–0–6
Research methods and techniques in the solution of marketing problems. Sampling; design of experiments; measuring market potentials, customer motivation and buying habits; sales forecasting; studies of competition; and measuring advertising and sales-force effectiveness. Limited-scale class project to provide experience in formulating a problem and conducting an exploratory investigation, determining types of data needed and methods of collecting them, gathering data, analyzing results, and reporting problem solution. *Maffei*

15.832 *Demand Analysis and Marketing Research* (A)
Prereq.: 15.025, 15.812
Year: G (2) 3–0–6
Application of quantitative methods to marketing research problems, with special emphasis on measurement of consumer demand. Usage of statistical tools of multiple regression, design of experiments, and sampling methods. Ways of securing valid information from market respondents, including relevant psychometric techniques. Computer programs used for data processing where appropriate. Class project to provide experience in planning and executing a research investigation with cooperating companies. *Maffei, Cunningham*

15.86 *Product Planning and Development* (A)
Prereq.: 15.812
Year: G (2) 3–0–6
The product mix as a major element in marketing strategy. Diversification policy. Sources of ideas for new or improved products and methods for screening such ideas in light of potential market demand, costs, prices, and suitability to company's production and marketing facilities; organizational relationships and methods used to insure coordination between production, research, marketing, financial and other company departments affected by production planning and development. Problems on transferring new products from development stage to regular production, package design, testing market acceptability, and planning introductory sales campaigns. *Cunningham*

15.91 *Business Practice and Policy Determination*
Prereq.: 15.41, 15.71, 15.81
Year: U (2) 3–0–6
A terminal subject dealing with the approach to general management problems affecting all facets of the enterprise. Discussions and readings tracing objectives, policy determinations, and practices of business units at all stages of growth from foundation to corporate maturity. Attempt to develop the integrative ability of students to use knowledge gained in core subjects and to prepare them for launching their careers in industrial management with a balanced understanding of their business as an entity. *Hudgins*

15.92 *Organization* (A)
Prereq.: 15.312, 15.371, 15.412, 15.712, 15.812
Year: G (1, 2) 3–0–6
Scientific studies of organization, especially business organization, brought together from any and all disciplines with emphasis on (a) the substantive findings; (b) the research methodologies employed; and (c) the scientific community and the research process as a source of information for executive use in the design and control of industrial organizations. Problem areas studied: organizational structure and process; leadership and morale; communication; control and evaluation; and decision-making. *Haberstroh*

15.93 *Business Practice and Policy Determination* (A)
Prereq.: 15.312, 15.412, 15.712, 15.812
Year: G (2) 3–0–6
Subject matter of 15.91 at advanced level. *Hudgins*

15.942 *Seminar in Business Practices* (A)
Prereq.: 15.18
Year: G (1) 3–0–6
Investigation of the principles of top management policy making. Derivation of authority, the corporate objective, influences on the decider, activation and appraisals of policy decisions. Case studies of selected companies illustrating the principles discussed. (*Restricted to Sloan Fellows.*) *Hudgins*

15.951–15.959 *Special Studies in Management* (A)
Prereq.: ——
Year: 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 field work, and reports. *Staff*

15.96 *Administrative Theory and Practice* (A)
Prereq.: 15.312, 15.412, 15.712, 15.812
Year: G (1) 3–0–6
Especially designed for graduate students who look forward to ultimate responsibilities in the top management of industry. Initial problems confronting the new business administrator. Formulation of methods of approach

to administrative problems. Techniques of negotiation, mediation and group deliberation. Relationships of top management to subordinates, investors, vendors, customers, associates, community, government, and the public. Underlying principles leading to long-term continuity and tenure. Evening conferences with business administrators and industrialists. *L. B. Moore*

15.971 *Seminar in Research Management* (A)
Prereq.: 15.371
Year: G (2) 2–0–7
Organizational and human relations aspects of managing laboratories and groups engaged in research and development, with consideration of the psychological and social factors in creative work. Readings, discussions, field studies, and reports. *Marquis*

15.975 *Seminar in Management of Improvement* (A)
Prereq.: 15.371
Year: G (1) 3–3–3
Examination of the improvement function in management. Review of literature on creativity as it affects innovation in industrial operation. Human relations problems in industrial change. The role of the manager in fostering improvement. The use of the conference as an improvement tool. Field work in comparative analysis of representative improvement programs.
L. B. Moore, Lodahl

15.98 *Seminar in Administration* (A)
Prereq.: 15.18
Year: G (1) 3–0–6
15.99 *Seminar in Administration* (A)
Prereq.: 15.18
Year: G (2) 3–0–6
Study of fundamental economic, financial, organizational and administrative relationships analyzed and discussed by experienced leaders in business, labor and public administration. Examination of managerial philosophies and practices in the field and in seminar discussions. (*Restricted to Sloan Fellows.*) *Wynne*

16.
Aeronautics and Astronautics

16.01T *Dynamics*
Prereq.: 8.02, 18.03
Year: U (1, S) 4–2–6
Dynamics, with applications to aeronautical and astronautical problems. Kinematics and dynamics of particles and of groups of particles. Relative motion as seen by accelerating and rotating observers. Particles of variable mass. Mass properties of rigid bodies, the inertia tensor, geometric and mass symmetries. Kinematics and dynamics of a rigid body in general motion. Euler's dynamical equations, gyroscope equations. *Halfman*

16.02 *Aerodynamics*
Prereq.: 2.401, *16.01T*
Year: U (1, 2) 4–2–6
Description of gaseous environment of vehicles in flight, considered as a continuous medium and from viewpoint of kinetic theory. Application of the conservation laws of mass, momentum and thermodynamic energy to real and perfect fluids in motion. One-dimensional flow of a perfect gas, with simple aeronautical and astronautical illustrations. Fundamentals of three-dimensional fluid motion; applications, with special reference to nonviscous incompressible flow; airfoil and wing theory. Elementary examples of viscous flow; boundary layer. *Ashley*

16.03 *Gasdynamics*
Prereq.: 2.401, *16.01T, 18.05*
Year: U (1) 4–2–6
Fundamentals of fluid dynamics presented so as to meet the needs of students interested in research. Physics and thermodynamics of gases from the phenomenological and atomistic viewpoints. Conservation laws for a continuous fluid medium and their specialization to nonviscous perfect gas. One-dimensional flow. Constant-density flow, with emphasis on the two-dimensional case. Introduction to small-perturbation concepts and to methods for analyzing compressible fluid motion. *Ashley*

16.041 *Aerodynamics — Viscous Fluids* (A)
Prereq.: 16.02, *18.05*
Year: G (1) 3–0–9
Introduction to viscous flows. Basic flow equations; exact solutions; low Reynolds number cases; boundary layer flows; brief discussion of stability; transition; turbulent boundary layers. Lectures to be supplemented by occasional demonstrations. *Bicknell, Finston*

16.042 *Aerodynamic Heating* (A)
Prereq.: 16.041, *18.06*
Year: G (2) 3–0–9
Extension of discussion in 16.041 to include thermodynamic aspects. Kinetic heating at high speeds; heat transfer through boundary layers; discussion of methods of reducing surface temperatures. Application to hypersonic aircraft and re-entry bodies, including real gas effects at high temperatures. *Finston*

16.051 *Topics in Gas Dynamics* (A)
Prereq.: 16.02 or 16.03; *18.05*
Year: G (1) 3–0–9
16.052 *Topics in Gas Dynamics* (A)
Prereq.: 16.051
Year: G (2) 3–0–9
Concepts for compressible medium flow. Fundamental conservation relations and nature of the medium. Methods appropriate for subsonic, transonic, supersonic, and hypersonic inviscid flows in two and three dimensions. Similarity concepts. Rarefied and real gas effects. Introduction to nonequilibrium flows. Application to bodies and wings. *Baron*

16.065 *Physics of High Speed Gas Flows* (A)
Prereq.: 16.02
Year: G (1) 3–0–9
Review of statistical mechanics as basis for the equations of motion of a gas. Physical nature of transport phenomena. Mechanism of vibrational excitation, dissociation, ionization, radiation and relaxation effects. Free molecule and slip flows. Introduction to magnetohydrodynamics and plasma flows. *Trilling*

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16.066 ***Problems in Hypersonic Flow*** **(A)**
Prereq.: 16.051
Year: G (2) 3–0–9
Rarefied gas flows and Newtonian flows; hypersonic flow past slender pointed and blunted bodies; flow past bluff bodies; hypersonic boundary layers. *Trilling*

16.07 ***Aerodynamics and Dynamics of Missiles*** **(A)**
Prereq.: 16.02, 16.11
Year: G (1) 3–0–6
Introduction to aerodynamic techniques useful for predicting performance and stability of slender vehicles in high-speed flight at all altitudes in planetary atmospheres. Flow of compressible fluid past bodies, wings, and more general configurations. Slender-body methods, Newtonian theory, other approximate techniques and their limitations. Estimation of forces and moments at subsonic, transonic, supersonic, and hypersonic speeds. Similarity laws and area rules. Some quasi-linear and nonlinear dynamic problems peculiar to slender vehicles. *Ashley*

16.081 ***Advanced Gas Dynamics*** **(A)**
Prereq.: 16.042 or 16.052 or 18.60; 18.06
Year: G (1) 3–0–9
16.082 ***Advanced Gas Dynamics*** **(A)**
Prereq.: 16.081
Year: G (2) 3–0–9
Two-semester subject for graduate students whose principal interest is fluid mechanics. Discussion of the equations of motion and their application to problems in acoustics, wake and jet flows, boundary layer flows, wave motion, and turbulence. Discussion of unsolved as well as solvable problems. *Mollö-Christensen*

16.10 ***Space Flight Dynamics*** **(A)**
Prereq.: 16.01
Year: G (2) 3–0–6
Satellite librations and some effects of nonspherical gravitational fields. Elementary inertial navigation and the Schuler pendulum. Calculus of variations in flight engineering with applications to dynamic aircraft performance and interplanetary rocket flight; classical minimum principles. General motion of "rigid" bodies of variable mass. Relativity and space flight. *Halfman*

16.105 ***Applied Aerodynamics*** **(A)**
Prereq.: 16.02, 16.11
Year: G (1) 3–0–6
Studies of flight vehicle performance including aerodynamics and characteristics of various types of power plant for a wide range of Mach numbers. *Ober*

16.11 ***Flight Vehicle Aerodynamics and Dynamics***
Prereq.: 16.01T; 16.02 or 16.03
Year: U (2, S) 4–0–5
Motions of flight vehicles under the action of aerodynamic and gravitational loads. Discussion of methods of predicting aerodynamic loads with special consideration of their validity. Small disturbance methods leading to classical dynamic stability of flight vehicles. *Bicknell*

16.15 ***Advanced Flight Vehicle Stability and Control*** **(A)**
Prereq.: 16.11
Year: G (1) 3–0–6
Analytic solutions for nonlinear problems in flight mechanics, including: phugoid motions, entry into planetary atmospheres at orbital speeds, deceleration processes, and flight at suborbital speeds. Linear approximations to flight vehicle dynamics, including: classical airplane stability theory, stability derivative estimation for contemporary aircraft, dynamic similarity laws, gust response, inertial cross coupling and spinning. Dynamics of simple aircraft-controller combinations. Analysis of flight test dynamic stability data. *Larrabee*

16.20T ***Flight Vehicle Structures I***
Prereq.: 16.201
Year: U (1, 2) 4–0–6
Theories of elasticity and plasticity in three-dimensional orthogonal curvilinear coordinates. Thermoelasticity. Specialization to solid sections, simple shells and stiffened skin structures under shear, bending torsion and compression; both elastic and plastic effects. Elementary concepts of stability. Principles of minimum weight design. Laboratory demonstrations. *Mar, Dugundji*

16.201 ***Solid Mechanics I***
Prereq.: 3.14
Year: U (2) 4–0–6
Fundamentals of solid mechanics presented to build upon the atomistic view as presented in an introductory subject in material science. Establishment of a connection between this viewpoint and the physics of solids on a phenomenological basis. Concepts of stress and strain. Equilibrium and compatibility of solids in three dimensions. Behavior and modes of failure of materials under extreme environmental conditions. Laboratory demonstrations. *Mar*

16.202 ***Solid Mechanics II***
Prereq.: 16.201
Year: U (2) 4–0–6
Theories of elasticity and plasticity in three dimensional orthogonal curvilinear coordinates. Tensor properties of stress and strain. Energy methods. Thermoelasticity. Elastic and plastic bending and twisting of beams. Concepts of stability. Elementary theory of plates including elastic and plastic buckling. Laboratory demonstrations. *Bisplinghoff*

16.21T ***Flight Vehicle Structures II***
Prereq.: 16.20T
Year: U (1) 3–1–6
Energy methods in solid and structural mechanics. Influence coefficients. Vibrations of structural components. Introduction to shell theory with applications to the analysis of flight vehicle shell structures with and without internal pressure. Analysis of rings and bulkheads. Theories of elastic and plastic stability with applications to flight vehicle shell structures. Laboratory experiments. *Dugundji*

16.22 ***Shell Structures*** **(A)**
Prereq.: 16.20T
Year: G (2) 3–0–6
General formulation of problems in shell structures of arbitrary shape using methods of tensor calculus. Effects of aerodynamic heating on stresses and distortion. Consideration of nonlinear phenomena including large displacements, "snap-through," and buckling. *Pian*

16.25 ***Advanced Theory of Structures*** **(A)**
Prereq.: 16.20T
Year: G (1) 3–0–6
Varying content from year to year as new methods for analysis of all-metal aircraft become available for examination. Probable effects on structural analysis methods to be expected from new trends in design. *Bisplinghoff*

16.30 ***Principles of Automatic Control***
Prereq.: 6.43, 16.01T
Year: U (2) 3–0–9
Analysis of automatic control systems, including analytical, graphical, and analog methods. Formulation of control system performance equations leading to solutions for transient and steady state inputs. Non-dimensionalized treatment of simple linear systems and extension to more involved automatic control loops. Selected aeronautical and astronautical control problems. *McKay*

16.31 ***Principles of Instrumentation and Control* (A)**
Prereq.: 16.30
Year: G (1) 3–0–9
Generalized concepts of system performance analysis based on frequency, transient and error coefficient methods. Combined use of feedback and programmed control systems for improving adaptive capability of systems under adverse environmental changes. Principles of system synthesis. Parameter adjustment for optimization of specific dynamic performance indices. Illustrative application of these principles to aircraft and missile systems. *Li*

16.32 ***Principles of Instrumentation and Control* (A)**
Prereq.: 16.31
Year: G (2) 3–0–9
System design with random inputs and disturbances. Analysis of system characteristics with time varying parameters. Nonlinear system performance analysis. Switching technique applied to control and instrumentation. Optimalizing control systems. Adaptive control system design principles for aircraft and spacecraft. Sampled data control system analysis. *Li*

16.33 ***Instrumentation and Control Laboratory* (A)**
Prereq.: 16.31
Year: G (1) 2–2–6
To be taken simultaneously with 16.31. Laboratory exercises on instruments and control systems designed to provide experimental familiarity with principles set forth in 16.31. Various test methods to evaluate static and dynamic characteristics of instruments and control systems. Various schemes for improvement of static and dynamic performance. *Li*

16.35 ***Special Problems in Instrumentation and Control* (A)**
Prereq.: 16.32
Year: G (1 or 2) *Arr.*
Problems of interest to qualified individual students in consultation with the instructor. *McKay*

16.36 ***Measurement, Telemetry and Data Processing* (A)**
Prereq.: 16.30
Year: G (2) 2–2–6
Measurement of physical quantities under various operating conditions and at remote locations. Methods of converting physical phenomena, such as pressure, vibration, flow rate, geometric position, to analog or digital signals suitable for transmission and data handling. Data processing techniques and specialized computations to reduce measured signals to a form better suited for specified application. Emphasis on accuracy, speed, and methods for overcoming disturbing effects at various stages of the system. *Li*

16.37 ***Statistical Problems in Automatic Control* (A)**
Prereq.: 16.30, 18.05
Year: G (1) 3–0–9
Statistical problems of importance to control engineers. Review of probability theory with application to such problems as evaluation of probability of kill. Introduction to sample theory with application to determination of the CPE for missile systems. Extensive treatment of random processes in linear feedback systems including optimum design of such systems; brief treatment of nonlinear systems in presence of random noise. *Vander Velde*

16.38 ***Physical Components of Control Systems* (A)**
Prereq.: 6.18
Year: G (2) 3–0–6
Effect of component performance characteristics on the control system problem. Consideration of mechanical, electrical and electromechanical components with emphasis on non-ideal effects. Specification of components to meet particular system requirements. Numerous lecture references to applications in aircraft, missile, and spacecraft guidance. *R. K. Mueller*

16.39 ***Space Dynamics and Gyroscopic Instruments* (A)**
Prereq.: 16.01T
Year: G (1) 3–1–6
Consideration of origins of inertial space concepts and application to interpretation of measured data. Generalized theory of accelerations and velocities of bodies in spaces which are moving with respect to inertial space. Application of general theory and of Newtonian mechanics to theory of gyroscopic instruments. Space integrators and stabilization. Development of treatment from standpoint of engineer, using methods of vectors and of conventional analysis. Application to gyroscopic devices in airborne and marine navigation. *Wrigley*

16.392 ***Inertial Guidance* (A)**
Prereq.: 16.39
Year: G (2) 3–0–6
Fundamentals of self-contained automatic marine, aircraft, and missile guidance. Character of terrestrial and extraterrestrial gravitational fields; space navigation. Force measurement for navigation purposes with accelerometers for position computation referred to gyroscopically maintained coordinate systems. Combinations of accelerometers, gyroscopes, and computers to form inertial guidance systems. Terrestrial navigation and Schuler tuning; computation of the geographic vertical from moving bases; damping and other system design problems. Effect of component uncertainties on system performance. Inertial control of vehicles to programmed paths. Utilization of possible environmental contact and measurement. *Wrigley*

16.40 ***Control Systems Principles***
Prereq.: 16.39
Year: G (1) 4–0–8
Analysis of automatic control systems, including analytic, graphical and analog computer methods. Response of systems described by linear and incrementally linear equations. Stability of feedback control systems. Non-dimensional treatment of linear constant-coefficient differential equations. System modification to control dynamic and interference errors. Examples chosen for flight vehicle systems. *Stockard*

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16.41 *Introduction to Weapons Systems* (RA)
Prereq.: 16.39, 16.40
Year: G (1, 2) 4–0–8
Static and dynamic behavior of weapons system components and subsystems from standpoint of functional performance, in terms of harmonic analysis and elementary classical physics. Development of a coherent pattern for associating solutions in terms of nondimensional variables with typical weapons system engineering problems. Numerical and graphical methods for determining transient stability of feedback systems. Limitations imposed by uncertainties and interferences on performance of physical equipment. Introduction to theoretical statement of fire control problem and to inertial navigation. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *Markey*

16.42 *Weapons Systems* (RA)
Prereq.: 16.41
Year: G (1, 2) 3–0–9
Generalized treatment of weapons systems problem and methods available for its solution by physical concepts and vectors. Application of gyroscopic and other equipment for interference isolation, tracking, and computing in weapons systems. Fire control principles for airborne and marine weapons systems. Fundamentals of inertial guidance and its application to ships, aircraft, missiles, and spacecraft. Examples taken from service systems. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *Wrigley, Markey*

16.43 *Weapons Systems Laboratory* (RA)
Prereq.: 16.42
Year: G (1, 2) 1–3–5
Demonstration of principles treated in 16.42. Various experiments on characteristics of fire control instrument components, including gyroscopic elements, data transmission systems, and integrating units. Experiments on service fire control equipment and special demonstration units to study static and dynamic performance characteristics of typical airborne and anti-aircraft equipment. Problems of solution time, smoothing, and tracking. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *R. K. Mueller*

16.44 *Automatic Control of Flight Vehicles* (A)
Prereq.: 16.11, 16.30, 16.39
Year: G (2) 3–0–6
Application of design techniques and principles to advanced automatic control systems for air and space vehicles. Synthesis of control systems from standpoint of meeting mission specifications. Analysis of adaptive control systems; their use in meeting performance requirements over widely changing environments encountered by high-speed aircraft and manned spacecraft. Typical engineering problems associated with design of control equipment, considering limitations and uncertainties of components, random input effects, mass cross-coupling effects, etc. *Whitaker*

16.46 *Astronautical Guidance* (A)
Prereq.: 16.392
Year: G (2) 3–0–6
Fundamentals of space vehicle navigation, guidance, and control with particular emphasis on the self-contained type. Extra-terrestrial trajectory determination; orbital injection problems; interplanetary celestial navigation; ballistic guidance for one-way and round-trip missions to the moon and planets; guidance of continuous low-thrust vehicles; guidance for satellite rendezvous; atmospheric reentry guidance. Effect of component inaccuracies on performance of missions. *Battin*

16.49 *Special Problems in Weapons Systems* (RA)
Prereq.: 16.42
Year: G (1 or 2) *Arr.*
Problems of interest to qualified students in consultation with the instructor. (*Restricted to selected officers of the U. S. Air Force, Army, and Navy.*) *Wrigley*

16.50 *Vertical Take-Off Aircraft* (A)
Prereq.: 16.11
Year: G (1) 3–0–6
Analysis of performance and inherent stability and control characteristics of vertical take-off and landing aircraft, VTOL, including helicopters, convertiplanes, tilt wing, vectored lift and jet vertical risers. *R. H. Miller*

16.51 *Advanced Vertical Take-Off Aircraft* (A)
Prereq.: 16.50
Year: G (2) 3–0–6
Application of fundamental principles of aeroelasticity, airplane dynamics, thermodynamics, and automatic control to problems encountered in the design of aircraft capable of vertical take-off and landing, VTOL. Problems of control and stability during conversion to horizontal flight, design of aircraft stabilization systems, dynamics of wing-rotor combinations and of rigid or articulated rotors, and analysis of specialized power plant requirements for direct jet lift. *R. H. Miller*

16.53 *Propulsion*
Prereq.: 2.25 or 16.02 or 16.03; 2.401
Year: U (1, 2, S) 3–0–6
Review of mechanics of compressible fluids. Applications to analysis and design of gas turbines, rockets, and ram jets. Limits on performance imposed by thermodynamics, fluid mechanics, and strength. *E. S. Taylor*

16.56 *Astronautical Propulsion* (A)
Prereq.: 2.051, 16.53, 18.06
Year: G (1) 3–0–9
Application of fundamental principles of fluid mechanics and thermodynamics to the analysis of selected special problems found in the research and development of liquid propellant engines and nuclear, ion, arc, and magnetohydrodynamic engines. Discussion of possible and most suitable application of the various engines. *E. S. Taylor, Oates*

16.60 *Advanced Aeronautical Problems* (A)
Prereq.: 16.11 or 16.20
Year: G (1 or 2) *Arr.*
Individual advanced work by properly qualified graduate students. Problems selected in consultation with the instructor. *Staff*

16.605 *Aeronautical Problems*
Prereq.: ——
Year: U (1 or 2) *Arr.*
Individual or group work by properly qualified students. Problems chosen in consultation with instructor. *Staff*

16.62 *Experimental Projects I*
Prereq.: 16.81
Year: U (1, 2) 2–4–4
Experimental projects in the field of aeronautics and astronautics. Emphasis on the role of the experimental method in relation to analysis, and on the student's responsibility in project leadership. *Staff*

16.63 *Experimental Projects II*
Prereq.: 16.62
Year: U (1) 2–6–4
Philosophy of 16.62 applied to more complex problems. *Staff*

16.66 *Fluid Dynamics Laboratory* (A)
Prereq.: 16.63
Year: G (1 or 2) *Arr.*
Graduate laboratory subject in fluid mechanics and related fields, conducted as individual projects arranged between student and instructor. *Mollö-Christensen*

16.70 *Aircraft Detail Design*
Prereq.: ——
Year: U (1) 3–5–0
Aircraft drafting room practice and the preparation of airplane assembly, subassembly, and detail part drawings. Lectures and drafting room exercises covering air frame detail design, landing gear and landing gear control system mechanisms, fuel systems, airplane graphics, and the preparation of a weight estimate and balance diagram for a complete airplane. *Bentley*

16.71 *Flight Vehicle Engineering*
Prereq.: 16.11, 16.20T
Year: U (1) 2–3–7

16.72 *Flight Vehicle Engineering*
Prereq.: 16.71
Year: U (2) 2–3–7
Design of an airplane or rocket vehicle including layout, weight, balance, and performance estimates, structural design and preliminary stress analysis, stability and control analysis. Emphasis on individual initiative and independent application of fundamental design principles and on presentation of a final report. *Koppen*

16.74 *Advanced Design* (A)
Prereq.: 16.105, 16.72
Year: G (1) 2–6–4
Application of current design and operations analysis methods to the determination of the optimum vehicle capable of satisfying a given mission. Weight estimation from preliminary structural design and aeroelastic considerations, performance substantiation, evaluation of functional suitability, control system analysis and determination of optimum propulsive device. Considerable latitude in the choice of mission; use of the vehicle primarily as a means of illustrating methods used during the preliminary design stages in the development of aircraft and rocket vehicles. *R. H. Miller*

16.761 *Orbital and Ballistic Flight* (A)
Prereq.: 16.01; 16.02 or 16.03
Year: G (1) 3–0–6

16.762 *Orbital and Ballistic Flight* (A)
Prereq.: 16.761
Year: G (2) 3–0–6
Performance of ballistic and orbital missiles and space craft. Atmosphere and space environment of vehicles; orbital mechanics; ballistic trajectories; performance parameters of rocket motors; powered flight and re-entry trajectories; guidance navigation and control as affecting flight mechanics and vehicle design; kinematics of interception trajectories, aerodynamics and structures of vehicle design; vehicles system design considerations. First term strongly oriented toward fundamental celestial mechanics and trajectory kinematics and dynamics; second term strongly oriented toward effects on vehicle design of component technologies. *Stever, Sandorff*

16.78 *Control and Guidance in Flight Transportation* (A)
Prereq.: 16.11, 16.30
Year: G (1) 3–0–6
Study of the functional and technical aspects of the overall air transportation problems associated with enroute navigation, landing and take-off, and traffic control. Consideration of the interrelationships between the characteristics of the airplane as a whole and the facilities, equipment, and environment, with the view of evolving a comprehensive solution to the air navigation and control problem that meets the desired system performance. Study of existing navigation, traffic control, and automatic control systems. *Whitaker*

16.81 *Flight Vehicles*
Prereq.: 8.01
Year: U (1) 3–0–6
The role of science and engineering in the development of aircraft and space craft. Examination of the fundamental problems and solutions of these problems in the light of current technology. *Draper*

16.82 *Introductory Aeronautical Engineering*
Prereq.: 18.03
Year: U (1) 3–0–3
Introduction to aircraft, their components and general principles of flight. *Markham*

16.85 *Industrial Practice*
Prereq.: ——
Year: U (1) 40 h.p.w.
Five months of practical work carried out by the cooperative students in manufacturing, engineering, research, and developments at the plants of organizations participating in the cooperative program. *R. H. Miller*

16.91 *Aeroelasticity* (A)
Prereq.: 16.02, *18.05*
Year: G (1) 3–0–6
Dynamics of elastic structures. Self-excited dynamic instability involving the interaction between elastic solids and air flow. Emphasis on formulation of self-excited vibration problems and approximate methods for their solution. *Mollö-Christensen*

16.92 *Advanced Aeroelasticity* (A)
Prereq.: 16.91
Year: G (2) 3–0–9
Presentation of field of aeroelasticity from unified viewpoint applicable to all types of flight vehicles throughout range of airspeeds. Derivation of aeroelastic operators and unsteady airloads from governing variational principles. Forced response, static and dynamic eigenvalues of simplified systems, one-dimensional structures and two-dimensional structures. Special topics of interest to the aeroelastician, with emphasis on aerodynamic operators. *Ashley*

16.94 *Dynamics of Structures* (A)
Prereq.: 16.21, 16.91
Year: G (2) 3–0–9
Fundamental variational principles in dynamics; Lagrange's equation and Hamilton's principle. Vibration characteristics of unrestrained elastic systems. Dynamic stresses produced during transient response of aircraft and missile structures to rapidly applied forces. Response of structures to continuous random disturbances. Propagation of elastic and plastic stress waves. *Witmer*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

17.

Building Engineering and Construction

17.401 ***Advanced Job Management*** **(A)**
Prereq.: 1.921
Year: G (1) 3–0–6
Development of the organization of large projects with reference to the initial economic survey, time schedules, job organization, and integration of construction procedures. The character of contract instruments, legal requirements for job insurance and the expedition of materials to accomplish speed and quality. *Dietz*

17.402 ***Construction Management Seminar*** **(A)**
Prereq.: 1.921
Year: G (2) 3–0–6
Continuation of 17.401 in seminar form. Diagnosis of failures and their causes; integration of the electrical, mechanical and sanitary services into building construction; analysis of architectural concepts in the light of existing construction procedures; study of professional relations in the conduct of contracting as a profession. Extensive contributions by the students. Field trips to illustrate difficult situations. Participation of contractors, architects and engineers from a variety of projects. Field surveys, library research papers, term paper. *Dietz*

17.42 ***Construction Analysis Seminar*** **(A)**
Prereq.: 1.921
Year: G (2) 2–0–4
Exploration of analytical approaches to solution of many variables entering into construction, including flow of components, structural problems, influence of site conditions, materials technology, economic feasibility and cost analyses affecting optimum solution. Case system largely employed. *Heger*

17.73 ***Materials — Wood, Plastics, Fabrics***
Prereq.: 8.02
Year: U (2) 3–0–3
Mechanical and physical properties of wood in relation to growth, structure and other characteristics which influence its use in construction and engineering. Strength, moisture content, preservative treatment, wood products, identification, and selection of species for various uses. Fundamental properties and uses of plastics; basic characteristics of coatings and fabrics used in construction. *Wood Handbook;* Dietz, *Construction Materials.* *Dietz*

17.74 ***Materials — Masonry and Metals***
Prereq.: 8.03
Year: U (1) 3–2–4
Primarily for architectural students with emphasis on masonry materials, concrete, and metals. Factors affecting the durability of masonry structures. Principles underlying metals, alloys, corrosion and welding of metals. About two-thirds of subject on masonry materials, and the balance on metals. Laboratory work testing brick and mortar; concrete and concrete beams; ferrous and non-ferrous metals; wood, plastics, and laminates; thermal conductivity of walls. Murray, *Masonry Materials; Laboratory Manual;* Williams & Homerberg, *Principles of Metallography.* *McGarry*

17.741 ***Mechanical Behavior of Plastics*** **(A)**
Prereq.: 3.14
Year: G (1) 3–2–4
Relation between 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. Laboratory on individual project basis investigating problems related to current Plastics Research Laboratory programs. *McGarry, R. D. Andrews*

17.742 ***Composite Materials*** **(A)**
Prereq.: 3.14
Year: 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. Discussion of failure mechanisms of chemical electrical and mechanical types. Laboratory on individual project basis investigating problems related to current Plastics Research Laboratory program. *McGarry, Bikerman*

17.743 ***Viscoelastic and Rheological Properties of Materials*** **(A)**
Prereq.: 3.14
Year: G (2) 3–0–6
Thorough consideration of modern theories of the viscoelastic and rheological properties of materials. Discussion of mathematical principles and basic phenomenological theory, formulated in terms of a distribution of relaxation times. Description of detailed physical mechanisms responsible for this behavior in various classes of materials. Particular attention to the case of plastics and other polymers in the solid state. Study of the behavior of asphalt, soils, wood, glasses, and metals. *R. D Andrews*

17.744 ***Fundamentals of Polymers***
Prereq.: 3.14 or 3.31
Year: U (2) 3–0–6
A comprehensive introduction to polymeric materials for those students wishing more complete treatment to follow 3.14 or 3.31. Physical rather than chemical approach. Discussion of the nature, structure, origin, preparation, use and properties of important plastics. Mechanical, electrical, optical, thermal, chemical properties and behavior; effects of composition and structure; methods of fabrication including molding, extrusion, forming, etc.; fundamentals of adhesion with polymers; fiber reinforced plastics. Several plant visits to observe industrial methods. *McGarry*

17.76 ***Research in Organic Materials*** **(A)**
Prereq.: 17.741
Year: G (1 or 2) *Arr.*
Laboratory subject conducted on an individual projects basis, affording the student an opportunity to pursue an investigation relating to the properties of organic materials at a research level. Projects chosen and research direction carried out by individual consultation with staff members. Extensive use of facilities in the Plastics Research Laboratory for work on plastic materials, including mechanical properties, optical properties (photoelastic effect), mechanism of reinforcement, adhesion, laminate design, chemical and mechanical nature of degradation and aging, properties of foams, and polymerization studies. *McGarry*

17.771 ***Cementitious Materials*** **(A)**
Prereq.: 3.14
Year: G (1) 3–2–4
Advanced study of cementitious materials including portland cements, limes, gypsum products, and other cements used in construction. Critical studies of the composition and physical properties of the cements, and of the effect of these properties on the bleeding, workability, and setting of cement pastes, heat evolution, the structure and dimensional stability of set cement pastes, and the development of strength. Detailed study of the properties of mortars and plasters as effected by composition and cement characteristics. Individually assigned laboratory projects based on the less common test procedures used for evaluating cements. Lea, *Chemistry of Cement and Concrete.* *Dietz*

17.772 ***Concrete*** **(A)**
Prereq.: 17.771
Year: G (2) 3–0–6
Advanced study of Portland cement concrete with attention to the effect of type and composition of cement, type and size of aggregate on such properties as soundness, volume stability, and durability. Advanced study of selected topics as concrete mix design, air entrainment, admixes, bleeding, and creep. No required text but frequent reading assignments from current literature on concrete. *Dietz*

17.78 ***Research in Cementitious Materials*** **(A)**
Prereq.: 17.772
Year: G (1 or 2) *Arr.*
Opportunity for laboratory investigation amplifying the work done in 17.771 and 17.772. *Dietz*

17.79 ***Construction Materials Seminar*** **(A)**
Prereq.: 1.43
Year: G (2) 2–0–4
Principals to be used for evaluation of materials and selection for applications in building construction. New materials and combinations emphasized. Basic requirements for judging suitability, determining specifications, and control of quality. *McGarry*

18.
Mathematics

18.00 ***Elementary Number Theory***
Prereq.: ——
Year: 1 (1) 2–0–4
Elementary theory of whole numbers, including such topics as divisibility, prime and composite numbers, greatest common divisors, solutions of equations in integers, the congruence notation and its application, sums of squares. *Franklin*

18.01 ***Calculus***
Prereq.: ——
Year: 1 (1) 3–0–6
Fundamental ideas of differential and integral calculus. Differentiation and graphical representation of algebraic functions and of the sine and cosine. Integration of simple algebraic and trigonometric functions. Applications to problems in geometry and mechanics: maxima and minima, velocity and acceleration, plane areas, volumes, arc length, areas of surfaces of revolution, center of gravity, moment of inertia. Study of analytic geometry of the straight line. Thomas, *Calculus and Analytic Geometry, 3d edition.* *Franklin*

18.02 ***Calculus***
Prereq.: 18.01
Year: 1 (2) 3–0–6
Further study of differentiation and integration: trigonometric, inverse trigonometric, exponential, logarithmic, and hyperbolic functions. Analytic geometry of the conic sections. Polar coordinates and parametric representation. Complex numbers. Elementary vector analysis. Thomas, *Calculus and Analytic Geometry, 3d edition.* *Franklin*

18.03 ***Calculus***
Prereq.: 18.02
Year: U (1, 2) 3–0–6
Vectors and analytic geometry in three dimensions. Partial differentiation. Multiple integration. Infinite series. Complex numbers. Thomas, *Calculus and Analytic Geometry, 3d edition.* *Franklin*

18.04 ***Differential Equations***
Prereq.: 18.03
Year: U (1, 2) 3–0–6
Treatment of ordinary differential equations. Introduction to the Laplace transform. Series solutions. Probability. Martin and Reissner, *Elementary Differential Equations;* and Lindgren and McElrath, *Introduction to Probability and Statistics.* *Franklin*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

18.05 ***Advanced Calculus for Engineers*** **(A, except Courses II, VI, VIII, XIII, XVI, XVIII, XXII)**
Prereq.: 18.04
Year: G (1); U (1, 2, S) 3–0–6

18.06 ***Advanced Calculus for Engineers*** **(A, except Courses II, XVI, XVIII, XXII)**
Prereq.: 18.05
Year: G (2); U (1, 2, S) 3–0–6

Vector analysis; orthogonal curvilinear coordinates. Functions of a complex variable; calculus of residues; conformal mapping. Ordinary differential equations; integration by power series; Bessel and Legendre functions. Characteristic-value problems; expansions in series of orthogonal functions, including Fourier series. Partial differential equations; characteristics; solution of classical equations of mathematical physics. Franklin, *Methods of Advanced Calculus.* *Hildebrand*

18.07 ***Review of Mathematics***
Prereq.: ——
Year: G (S) 8–0–12

Review of calculus and differential equations. (Primarily for selected officers of the U. S. Army, Air Force, Navy and Coast Guard.) Douglass and Zeldin, *Calculus and Its Applications;* Martin and Reissner, *Elementary Differential Equations;* and Lindgren and McElrath, *Introduction to Probability and Statistics.* *Briney*

18.08 ***Topics in Discrete Mathematics***
Prereq.: ——
Year: 1 (2) 2–0–4

Elementary topics in: propositional logic; algebra of sets; permutations and combinations; probability; vectors and matrices; mathematical models and axiomatic method *H. Rogers*

18.10 ***Elementary Statistics***
Prereq.: 18.03
Year: U (1, 2) 3–0–6

Elementary subject in theory of probability and random variables. In latter part of material, techniques to be specialized in development of statistical methodology. Beta and Gamma functions, probability, discrete and continuous random variables, joint distributions, derived distributions, mathematical expectation, hypothesis testing, estimation and standard tests. Illustrations of practical applications. *Wadsworth*

18.11T ***Operations Research*** **(A)**
Prereq.: 18.05 or 18.21; 18.10
Year: G (1) 3–0–9

Theory of probability and random variables; emphasis on mathematical models having important applications in the field of operations research. Problems involving maximization with limited total effort, search theory, queueing theory, time series, stochastic processes, difference equations, and generating functions. Examples of physical and laboratory operations; illustrations from the fields of production, inventory control, reliability, maintenance, and military operations research.
Wadsworth

18.13 ***Numerical Analysis*** **(A)**
Prereq.: 18.05
Year: G (1) 3–2–7

18.14 ***Numerical Analysis*** **(A)**
Prereq.: 18.13
Year: G (2) 3–2–7

Introduction to the theory and practice of the solution of equations, interpolation, numerical differentiation and integration, and the numerical solution of ordinary and partial differential equations. Additional topics from the following: summation of series, least-squares methods, smoothing of data, Gaussian quadrature, Chebyshev approximation, harmonic analysis, approximation by exponential functions and by rational functions, determination of characteristic numbers of matrices. Hildebrand, *Introduction to Numerical Analysis.* *Hildebrand*

18.142 ***Special Topics in Numerical Analysis*** **(A)**
Prereq.: 18.06 or 18.13
Year: G (2) 3–0–9

A detailed study of numerical methods for solving partial differential equations, with emphasis on problems in continuum mechanics. A basic knowledge of partial differential equations and some familiarity with numerical methods assumed. *(Not offered 1961–62.)*

18.15 ***Methods of Applied Mathematics*** **(A, except XVIII)**
Prereq.: 18.05
Year: G (1, 2) 3–0–9

Operations with matrices and determinants; linear vector spaces; characteristic-value problems. Techniques of calculus of variations; Hamilton's principle and Lagrange's equations; variational principles for deformable bodies; direct and semi-direct methods. Formulation and solution of linear difference equations. Formulation and treatment of integral equations; Green's function; analytical and numerical methods of solution. Hildebrand, *Methods of Applied Mathematics.* *Hildebrand*

18.16 ***Heuristic Programming*** **(A)**
Prereq.: 6.41 or 6.539 or *18.18* or 18.89; 18.04
Year: G (2) 3–0–9

Discussion of the problem of making machines behave intelligently. Theory of automata, neural nets, and other computing structures. Application of such machines to learning, induction, pattern recognition, game playing, theorem proving, and other areas where problems can be solved by heuristic programming. *Minsky*

18.18 ***Probability***
Prereq.: 18.05
Year: U (2) 3–0–6

Elements of combinatorial analysis. Random variables and expectations. Laws of large numbers. The central limit theorem and its applications. Recurrent events and Markov chains. W. Feller, *An Introduction to Mathematical Probability and Its Applications.* *G. B. Thomas*

18.20 ***Linear Algebra***
Prereq.: 18.04
Year: U (1, 2) 3–0–6

Vector spaces, euclidean spaces, linear transformations, linear equations, matrices, determinants, quadratic forms, canonical forms of matrices. Hoffman and Kunze, *Linear Algebra.* *Schafer*

18.21 ***Analysis***
Prereq.: [illegible]
Year: U (1) 3–0–9

18.22 ***Analysis***
Prereq.: 18.20 or *18.26*; 18.21
Year: U (2) 3–0–9

Real numbers and euclidean n-space; Bolzano-Weierstrass and Heine-Borel theorems, Cauchy condition. Infinite series of real and complex numbers, tests for convergence, power series. Real valued functions, continuity, uniform continuity, bounded variation. Riemann-Stieltjes integration. Infinite series of functions, uniform convergence, differentiation and integration of series of functions. Taylor's theorem, Weierstrass approximation theorem, Fourier series, completeness of the trigonometric functions, Fejer's theorem. Orthogonal functions, Bessel's inequality, Parseval's equality. Jacobians and inverse function theorem, implicit function theorem, functional dependence. Change of variables in multiple integrals, line and surface integrals. Stokes', Green's, and divergence theorems. *G. B. Thomas*

18.23 *Senior Seminar in Mathematics*
Prereq.: 18.21
Year: U (1, 2) 3–0–9
Seminars for senior mathematics majors in several topics, each under the direction of a faculty member whose special interest is in the field of the seminar. Reports and discussion by students on topics taken from current journals or from texts not regularly used in other mathematics subjects. Certain topics may require an additional prerequisite. *Staff*

18.24 *Elementary Differential Geometry*
Prereq.: 18.22
Year: U (2) 3–0–6
Plane and space curves. First and second differential form of a surface. Theorems of Meusnier and Euler. Lines of curvature, asymptotic lines, conjugate lines, geodesics. Theorems of Gauss and Codazzi. Developable surfaces, surfaces of rotation, Liouville surfaces. Differential parameters. Problems of mapping. *Franklin*

18.241 *Introduction to Topology*
Prereq.: 18.21 or *18.25*
Year: U (1) 3–0–9
Topological spaces, connectedness, compactness, continuous functions, separation axioms, product space and function space topologies, plus several additional topics to be chosen by the instructor. *Stasheff*

18.242 *Riemannian Geometry*
Prereq.: 18.22, 18.241
Year: U (2) 3–0–9
First and second fundamental forms, geodesics, curvature, spaces of constant curvature, rigidity, Gauss-Bonnet theorem (with emphasis on one- and two-dimensional cases). *Helgason*

18.25 *Modern Algebra*
Prereq.: 18.04
Year: U (1) 3–0–9

18.26 *Modern Algebra*
Prereq.: 18.25
Year: U (2) 3–0–9
Groups, subgroups, factor groups, homomorphism theorems; rings and ideals, factorization theory for Euclidean rings; vector spaces and elementary field theory. Modules over a ring of operators. Applications to vector spaces and linear algebra. Normal forms for matrices. Quadratic forms. Tensor and Grassman algebras. *Iwasawa*

18.27 *Introduction to Functions of a Complex Variable* (A, except XVIII)
Prereq.: 18.04
Year: G (1) 3–0–9

18.28 *Introduction to Functions of a Complex Variable* (A, except XVIII)
Prereq.: 18.27 or 18.31
Year: G (2) 3–0–9
Complex numbers, analytic functions, Riemann surfaces for certain functions, Cauchy's theorem, singularities, residues, contour integral, conformal mapping, Schwarz-Christoffel transformation, series and sequences, analytic continuation, harmonic functions, conjugate functions, the gamma function, second order linear differential equations and special functions, Laplace transforms, asymptotic series, saddlepoint method, Hilbert transforms. *N. Levinson*

18.29 *Intermediate Differential Equations*
Prereq.: 18.03
Year: U (2) 3–0–9
First-order nonlinear differential equations. Second-order linear differential equations. Existence theorems. Successive approximations and Cauchy polygons. Plane autonomous systems. Regular singular points in the complex domains. Sturm-Liouville systems; special functions; Bessel, Legendre, and related functions. (*Not offered 1961–62.*) *Rota*

18.292 *Intermediate Differential Equations*
Prereq.: 18.03
Year: U (2) 3–0–9
Theory and methods of numerical integration of differential equations. Asymptotic estimates of eigenvalues and eigenfunctions, eigenfunction expansions. Asymptotic integration of linear differential equations. Nonlinear oscillations. (*Not offered 1961–62.*) *Rota*

18.31 *Theory of Functions* (A)
Prereq.: 18.21
Year: G (1) 3–0–9
Complex numbers, Riemann sphere, plane topology, fractional linear transformations. Complex integration, Cauchy's theorem, Cauchy's integral formula, power series, winding numbers, rational functions. Singularities, simple Riemann surfaces, local mapping theorem. Evaluation of definite integrals. Integral and meromorphic functions, expansions, special functions. Riemann mapping theorem. *Helgason*

18.32 *Theory of Functions* (A)
Prereq.: 18.31
Year: G (2) 3–0–9
Topics selected by the instructor, e.g., harmonic functions, Dirichlet problem, Green functions, conformal mapping, Riemann surfaces, differentials, integral functions, Fourier and Laplace transforms, Wiener-Hopf equations, special functions, prime number theorem. *McKean*

18.33 *Functions of Complex Variables* (A)
Prereq.: 18.31, 18.35
Year: G (2) 3–0–9

18.34 *Functions of Complex Variables* (A)
Prereq.: 18.33
Year: G (2) 3–0–9
Boundary values of analytic functions in the disc. Theorems of Fatou and Riesz. H^p-spaces. Approximation theorems of Runge, Walsh, Lavrentiev, and Mergelyan. Content varying from year to year, so that students may take the subject in successive years. (*Not offered 1961–62.*) *K. M. Hoffman*

18.35 *Functions of Real Variable* (A)
Prereq.: 18.22
Year: G (1) 3–0–9

18.36 *Functions of Real Variable* (A)
Prereq.: 18.35
Year: G (2) 3–0–9
Elements of the theory of metric spaces, category and Baire theorem. Lebesgue integration, absolute continuity and differentiation of functions of bounded variation. Abstract measure theory, Radon-Nikodym and Fubini theorems, L^p spaces. Independent random variables, Rademacher functions, law of large numbers, and maximal ergodic theorem. Elements of Banach spaces, Hahn-Banach and closed graph theorems. Topics on linear transformations on L^p spaces. *Glimm*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

18.363 ***Abstract Analysis*** **(A)**
Prereq.: 18.25 or 18.71; 18.36
Year: G (1) 3–0–9
18.364 ***Abstract Analysis*** **(A)**
Prereq.: 18.363
Year: G (2) 3–0–9
Basic theoretical results about the structures of a mixed analytical-algebraic-geometrical character that are significant in modern analysis. Integration, linear topological spaces and algebras, spectral theory, rings of operators in Hilbert space, group representations. Illustrative applications to harmonic analysis, probability, partial differential equations. (*Not offered 1961–62.*) *Segal*

18.365 ***Analysis in Function Space*** **(A)**
Prereq.: 18.36
Year: G (1) 3–0–9
General theory of integration and harmonic analysis in spaces of an infinite number of dimensions, especially Hilbert space, with applications to the Wiener and Feynman integrals, to quantum fields, and to stochastic processes. *Segal*

18.37 ***Functional Analysis*** **(A)**
Prereq.: 18.22 or 18.35; 18.31
Year: G (1) 3–0–9
18.38 ***Functional Analysis*** **(A)**
Prereq.: 18.37
Year: G (2) 3–0–9
Locally convex topological vector spaces, Banach spaces. Completely continuous operators. Banach algebras. Spectral theorem for operators in Hilbert space. Algebras of bounded operators in Hilbert space. Semigroups of operators. (*Not offered 1961–62.*) *K. M. Hoffman*

18.41 ***Differential Equations*** **(A)**
Prereq.: 18.15 or 18.20; 18.31
Year: G (1) 3–0–9
18.42 ***Differential Equations*** **(A)**
Prereq.: 18.41
Year: G (2) 3–0–9
Existence theorems in real and complex cases. Linear systems. Regular singular points. Irregular singular points and asymptotic series. Boundary value problems including the non-self adjoint case and the case of infinite intervals. Stability theory and perturbation theory for non-linear differential equations. Periodic orbits. Limit cycles. Differential equation on a torus. (*Not offered 1961–62.*) *N. Levinson*

18.43 ***Partial Differential Equations*** **(A)**
Prereq.: 18.06 or 18.21
Year: G (1) 3–0–9
18.44 ***Partial Differential Equations*** **(A)**
Prereq.: 18.43
Year: G (2) 3–0–9
Geometric approach to first and second order partial differential equations. Characteristics and wave fronts. Stress on second order equations. Boundary value problems, initial value problems. Adjoint equation, variational methods, operational methods. Maximum principle. Applications. *Ambrose*

18.441 ***Advanced Partial Differential Equations*** **(A)**
Prereq.: 18.36
Year: G (1) 3–0–9
18.442 ***Advanced Partial Differential Equations*** **(A)**
Prereq.: 18.441
Year: G (2) 3–0–9
Regularity properties of solutions of elliptic boundary value problems; spectral theory of elliptic and hypoelliptic differential operators; applications to initial value problems for parabolic and hyperbolic equations. *Browder*

18.47 ***Fourier Series and Integrals*** **(A)**
Prereq.: 18.21 or 18.31
Year: G (1) 3–0–9
Elementary theory of Fourier series and integrals as developed along modern lines. Stress on practical applications and development of the necessary analysis from the beginning. *Wiener*

18.53 ***Theory of Probability*** **(A)**
Prereq.: 18.22 or 18.35
Year: G (1) 3–0–9
18.54 ***Theory of Probability*** **(A)**
Prereq.: 18.53
Year: G (2) 3–0–9
Probability measures, Borel fields, conditional probabilities, sums of independent random variables, limit theorems, zero-one laws, topics on martingales, Markov processes, stationary processes and their connections with other parts of mathematics, especially with differential and integral equations. *McKean (18.53), Ray (18.54)*

18.60 ***Introduction to Fluid Mechanics***
Prereq.: 18.05, *18.06*
Year: U (1) 3–0–6
Elements of the theory of perfect fluids; fundamental concepts and basic relations. Theory of potential motions. Motion of rectilinear vortices. Gravity waves and related free surface problems. Application of the theory of complex variables. Elements of the theory of viscous fluids. Some exact solutions. Low-speed flow. Boundary layer theory. *Benney*

18.61 ***Theoretical Fluid Mechanics*** **(A)**
Prereq.: 18.60
Year: G (1) 3–0–9
Recapitulation of general theory of perfect fluids. One-dimensional motion. Two-dimensional motion involving subsonic and supersonic speeds; application of the theory of complex variables. Application of the theory of characteristics to hydrodynamical problems. Three-dimensional motion involving subsonic and supersonic speeds; theory of lifting surfaces. Other topics. *Greenspan*

18.62 ***Hydrodynamic Stability and Turbulence*** **(A)**
Prereq.: 18.60
Year: G (2) 3–0–9
Theory of turbulent motion. Review of the basic equations of hydrodynamics. Statistical theory of turbulence, kinematics, correlation, and spectral representations. Dynamics of homogeneous turbulence, similarity concepts, Kolmogoroff's theory, Heisenberg's theories, the quasi-Gaussian approximation. Turbulent diffusion and transfer, molecular theory of diffusion, the problems of random walk and Brownian motion, diffusion and dispersion by continuous movements, empirical methods. Introduction to the theory of hydrodynamic stability. (*Not offered 1961–62.*) *Lin*

18.63 ***Mathematical Theory of Magneto-Fluid Mechanics*** **(A)**
Prereq.: 8.041, 18.60
Year: G (2) 3–0–9
Maxwell equations, Lorentz transformation, discussion of the nature of approximation in hydromagnetics. Stress tensor, conservation theorems, scalar and tensor virial theorems. Equilibria, curl-free and force-free fields, incompressible "stars," pinches, steady flows. Hydromagnetic waves, stability, organized oscillations. (*Not offered 1961–62.*)

18.631 ***Stability Problems in Plasma Dynamics*** **(A)**
Prereq.: 8.721, 18.06
Year: G (1) 3–0–9
General introduction to magnetohydrodynamics and plasma physics. Magnetohydrostatic equilibrium. Stability problems in magnetohydrodynamics. Plasma oscillations. Micro-instability of plasmas. *Lüst*

18.64T *Wave Motion* (A)
Prereq.: 18.60
Year: G (2) 3–0–9
Nonlinear wave motion, theory of characteristics, shock waves, compression waves in gases, blast waves, supersonic flow, stability and diffraction of shock waves, mathematics of shock waves with relaxation effects or chemical reactions. Brief discussion of magnetohydrodynamic waves. Water waves, shallow water theory, floods and bores in rivers, capillary and gravity waves, ship waves, solitary and conoidal waves. (*Not offered 1961–62.*) *Whitham*

18.641 *Vector Analysis and Calculus of Variations*
Prereq.: 18.21
Year: U (1) 3–0–9
Vector algebra, vector calculus, integral theorems, general coordinates, potential theory, harmonic functions, scalar and vector potentials, retarded potentials. Introduction to tensor analysis. Index notation, cartesian tensors and their applications. Calculus of variations. Typical problems. Euler equations. Constraints. Natural boundary conditions, variational problem for a given differential equation. Second variation. (*Not offered 1961–62.*) *L. N. Howard*

18.642 *Introduction to Partial Differential Equations*
Prereq.: 18.22, 18.641
Year: U (2) 3–0–9
Basic concepts. The initial-value problem. Partial differential equations of the second order. Linear equations and their classification. Principle of superposition. The Laplace equation. The wave equation. The diffusion equation. Existence, uniqueness and stability. Linear equations of higher orders. Eigenfunctions and eigenvalues. (*Not offered 1961–62.*) *L. N. Howard*

18.65 *Integral Equations* (A)
Prereq.: 18.04
Year: G (2) 3–0–9
Objectives: (1) to show how to express physical problems in the form of integral equations, (2) to provide a treatment of the theory of integral equations, and (3) to describe the methods available for solving such equations. Applications to problems arising in several branches of physics and engineering. *Crout*

18.651 *Introduction to Applied Mathematics*
Prereq.: 18.21
Year: U (1) 3–0–9
18.652 *Introduction to Applied Mathematics*
Prereq.: 18.651
Year: U (2) 3–0–9
Mathematical solution of physical problems, examples. Vectors and Cartesian tensors, integral theorems, curvilinear coordinates, introduction to tensor analysis. Maxwell equations, equations of continuum mechanics, boundary conditions, and initial conditions. Elements of potential theory. Analytic functions of a complex variable. Linear partial differential equations with constant coefficients, classification. Existence, uniqueness, and stability of solutions. Method of finite differences, convergence, stability. Method of separation of variables. Fourier series, eigenvalues and eigenfunctions. Green's function, integral equations. Elements of calculus of variations. Asymptotic methods. Discussion of physical problems as illustrations of the methods and principles being considered. Jeffreys and Jeffreys, *Methods of Mathematical Physics*, 3d edition. (*Credit will not be given for 18.651,2 if credit has already been received in 18.641,2.*) *Lin*

18.653 *Advanced Methods of Applied Mathematics I* (A)
Prereq.: 18.27
Year: G (1) 3–0–9
18.654 *Advanced Methods of Applied Mathematics II* (A)
Prereq.: 18.653
Year: G (2) 3–0–9
Review of functions of a complex variable; asymptotic expansions; method of steepest descents for integrals, and related topics; linear ordinary differential equations; special functions; Laplace transforms. First and second order partial differential equations; classification; characteristics; typical initial and boundary value problems; fundamental solutions and Green's functions; eigenfunction expansions; transforms. Applications.
Toomre (18.653), Greenspan (18.654)

18.655 *Advanced Methods of Applied Mathematics III* (A)
Prereq.: 18.28 or 18.654
Year: G (1) 3–0–9
Integral equations: survey of Hilbert-Schmidt and Fredholm theories; singular integral equations; transform techniques; the Wiener-Hopf method; the Hilbert problem; dual integral equations; approximation methods; applications; selected topics from the calculus of variations and perturbation theory. *Hunter*

18.66 *Introduction to Elasticity*
Prereq.: 18.05
Year: U (2) 3–0–6
Elements of stress and strain in two and three dimensions. Hooke's Law, including thermal effects. St. Venant torsion theory. Problems of the elastic half space. (*Not offered 1961–62.*) *Reissner*

18.67 *Theoretical and Applied Elasticity* (A)
Prereq.: 2.081 or 18.66; 18.06
Year: G (1) 3–0–9
18.68 *Theoretical and Applied Elasticity* (A)
Prereq.: 18.67
Year: G (2) 3–0–9
Analysis of stress and strain in three dimensions. Stress-strain relations. Variational principles in elasticity, including application to the approximate solution of boundary value problems. Theories of torsion, of flexure and of plane stress and strain. Bending of flat plates, linear and non-linear theory. Bending and stretching of thin shells. Elastic stability theory. Elements of the finite deformation theory of elasticity.
Reissner (18.67), Kröner (18.68)

18.69 *Tensor Calculus* (A)
Prereq.: 18.15 or 18.20
Year: G (2) 3–0–9
Classical theory of tensors and Riemannian geometry. Applications to mechanics and general relativity. Introduction to the modern theory of differential forms.
Toomre

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

18.721 ***Algebraic Geometry*** **(A)**
Prereq.: 18.25
Year: G (1) 3–0–9
18.722 ***Algebraic Geometry*** **(A)**
Prereq.: 18.721
Year: G (2) 3–0–9
Introduction to the theory of algebraic varieties over arbitrary ground fields. Basic properties, rational maps and correspondences; linear systems and Riemann-Roch theorem for curves and surfaces; algebraic groups and abelian varieties; sheaf theoretic methods. (*18.722 not offered 1961–62.*) *Mattuck*

18.731 ***Algebra*** **(A)**
Prereq.: 18.20 or 18.26; 18.25
Year: G (1) 3–0–9
18.732 ***Algebra*** **(A)**
Prereq.: 18.731
Year: G (2) 3–0–9
Theory of fields and their extensions: algebraic and transcendental extensions, Galois extensions, algebraic closures. Structure of groups and rings. Linear algebra. (*Credit will not be given for 18.731 or 18.732 if credit has already been received in 18.73.*) (*18.732 not offered 1961–62.*) *Ankeny* (*18.731*), *Iwasawa* (*18.732*)

18.74 ***Topics in Algebra*** **(A)**
Prereq.: 18.731
Year: G (2) 3–0–9
Content varies yearly so that graduate students may take the subject in successive years. Topics in the past few years have included algebraic number theory, algebraic groups, noncommutative rings and algebras. *Schafer*

18.763 ***Algebraic Number Theory*** **(A)**
Prereq.: 18.73
Year: G (1) 3–0–9
18.764 ***Algebraic Number Theory*** **(A)**
Prereq.: 18.763
Year: G (2) 3–0–9
Study of algebraic number fields and function fields, local and global, with emphasis on the sheaf-like viewpoints which generalize to algebraic groups and on cohomological methods. Ideals, ideles, and adeles; valuation theory. Splitting laws, group of units, class numbers, brief discussion of analytic methods. Cohomology of groups and class field theory for number fields and algebraic curves. (*Not offered 1961–62.*)
Mattuck (*18.763*), *Ankeny* (*18.764*)

18.77 ***Theory of Numbers***
Prereq.: 18.20 or *18.25; 18.21*
Year: U (2) 3–0–9
Study of 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. Elementary proof of the prime number theorem. *Iwasawa*

18.78 ***Topics in the Theory of Numbers*** **(A)**
Prereq.: 18.31
Year: G (1) 3–0–9
18.79 ***Topics in the Theory of Numbers*** **(A)**
Prereq.: 18.78
Year: G (2) 3–0–9
Discussion of the Riemann Zeta function. Proof of the prime number theorem through contour integration, the method of contour integration applied to the divisor problem, the solution of Waring's problem via the circle method of Hardy-Littlewood and Vinogradoff's improvements, other applications of the circle method, the general sieve method of Selberg with application to primes, twin primes, Goldbach's problem. Proofs of certain best possible results of the sieve. Content varying from year to year, so that graduate students may take the subject in successive years. (*Not offered 1961–62.*) *Ankeny*

18.80 ***Topics in Foundations of Mathematics*** **(A)**
Prereq.: 18.20 or 18.25
Year: G (2) 3–0–9
Topics in mathematical logic, effective computability, and axiomatic set theory, with emphasis on the second of these. Brief study of certain classical systems of mathematical logic with related results. (*Not offered 1961–62.*)
H. Rogers

18.81 ***Topology*** **(A)**
Prereq.: 18.241, *18.25*
Year: G (1) 3–0–9
18.82 ***Topology*** **(A)**
Prereq.: 18.81
Year: 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. *Peterson*

18.83 ***Advanced Topology*** **(A)**
Prereq.: 18.82
Year: G (1, 2) 3–0–9
Content varying from term to term so that graduate students taking the subject in successive terms may have an introduction to several important phases of topology, such as homotopy theory, cohomology theory, sheaf theory, combinatorial topology, and/or differential topology. *Munkres, G. W. Whitehead*

18.84 ***Locally Compact Groups*** **(A)**
Prereq.: 18.35 or 18.37
Year: G (2) 3–0–9
Haar measure, group algebras, unitary representations, harmonic analysis on compact and abelian groups, Plancherel theorem, duality theorem. (*Not offered 1961–62.*) *I. M. Singer*

18.85 ***Continuous Groups*** **(A)**
Prereq.: 18.35, *18.81*
Year: G (1) 3–0–9
18.86 ***Continuous Groups*** **(A)**
Prereq.: 18.85
Year: G (2) 3–0–9
The classical groups. Correspondences of Lie groups and Lie algebras. Structure theory of Lie algebras. Classification of semisimple Lie algebras and their representations. Topology of Lie groups. Discussion of symmetric spaces. (*18.86 not offered 1961–62.*)
Kostant (*18.85*), *Ambrose* (*18.86*)

18.87 ***Geometry of Manifolds*** **(A)**
Prereq.: 18.22, *18.81*
Year: G (1) 3–0–9
18.88 ***Geometry of Manifolds*** **(A)**
Prereq.: 18.87
Year: G (2) 3–0–9
Real and complex manifolds, Riemannian and Hermitian manifolds, differential forms, connexions and their curvature forms. Study of global properties of complete Riemannian manifolds under various curvature assumptions. The Gauss-Bonnet theorem, the Weil homomorphism, and characteristic cohomology classes. The Hodge theorem on harmonic forms, and its application to Kähler manifolds. Morse theory for Riemannian manifolds. (*Not offered 1961–62.*) *I. M. Singer*

18.89 *Mathematical Logic* (A)
Prereq.: 18.20 or 18.25
Year: G (2) 3–0–9
Classical systems of logic; their use in the formalization of mathematical argument. Algebraic structure in logical systems. Brief study of effective computability, Godel incompleteness theorem, related topics. *H. Rogers*

18.892 *Mathematical Logic* (A)
Prereq.: 18.89
Year: G (2) 3–0–9
Theory of models. Axiomatic set theory. Relative consistency, undecidability, and incompleteness. Recursive function theory. (*Not offered 1961–62.*) *H. Rogers*

18.90 *Mathematical Reading* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Reading of advanced mathematical treatises under the supervision of some member of the department. Choice of treatise and allotment of time according to individual cases. For graduate students finding it desirable to do advanced work not provided for in the regular subjects. Open to undergraduates only under exceptional circumstances. *W. T. Martin*

18.91 *Seminar in Mathematics* (A)
Prereq.: 18.06 or 18.22 or 18.31
Year: G (1 or 2) *Arr.*
Reading, consultation and discussion of current mathematical research. (*Not offered 1961–62.*) *N. Levinson*

19.
Meteorology

19.003 *Elementary Meteorology I*
Prereq.: ——
Year: 1 (2) 2–0–4
Introduction to meteorological science through examples from all scales of atmospheric motions; radiation balance and the global circulation; air masses and fronts; cyclones and weather forecasting; hurricanes; sea breeze; thunderstorms; micrometeorology; cloud physics; climatology. Laboratory exercises with weather maps. *J. M. Austin*

19.02 *Descriptive Meteorology*
Prereq.: ——
Year: U (2) 3–0–6
The general circulation of the earth's atmosphere; the secondary circulations, both tropical and extratropical, including the role of air masses and fronts; the tertiary (local) circulations, including drainage winds, local convection, whirlwinds, showers, thunderstorms, land and sea breeze, large scale turbulence eddies, föhn winds, etc. Willett and Sanders, *Descriptive Meteorology*, 2nd ed. *Willett*

19.14 *Long-Range Weather Forecasting* (A)
Prereq.: 19.44
Year: G (1) 3–8–6
Physical and statistical analysis of large-scale changes of the general circulation, with emphasis on the variable solar influences and climatic trends. Review of extended and long-range forecasting techniques. Laboratory exercises on the application of the Weather Bureau five-day prognostic technique. *Willett*

19.15 *Long-Range Forecasting* (A)
Prereq.: 19.44
Year: G (1) 3–0–6
Lecture part of 19.14. *Willett*

19.22 *Meteorological Instruments* (A)
Prereq.: 19.02
Year: G (2) 3–2–6
Laboratory study of the design and response characteristics of current surface and upper air instruments, with reference to the meteorologist's requirements. *Keily*

19.23 *Micrometeorological Instrumentation* (A)
Prereq.: 19.02
Year: G (1) 2–2–4
Design and evaluation of measuring systems for use in the lowest levels of the atmosphere. For graduate students specializing in micrometeorology. *Keily*

19.30 *General Metecrology*
Prereq.: ——
Year: U (2) 2–0–4
Distribution of radiation, temperature, pressure and wind, hydrometeors and air masses and fronts at the surface of the earth and aloft and of the physical factors determining this distribution. The basic physical principles involved in such atmospheric systems as land- and sea-breezes, thunderstorms, tornadoes, hurricanes, and cyclones. *J. M. Austin*

19.34 *Statistical Methods in Meteorology*
Prereq.: 18.04, *19.51*
Year: G (1) 2–0–4
Designed to examine recent developments in statistical weather forecasting and to provide a background for performing and evaluating statistical studies with meteorological data. Statistical forecasting by linear regression, nonlinear statistical forecasting, significance of empirical relations, and hypothesis testing. *Lorenz*

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19.35 *Statistical Problems in Meteorology* (A)
Prereq.: 19.34
Year: G (2) 2–0–4
Seminar in statistical problems in meteorology, including such topics as power spectrum analysis, properties of stationary time series, and evaluation of linear and nonlinear methods of statistical weather forecasting. *Lorenz*

19.43 *Synoptic Meteorology I*
Prereq.: 19.601
Year: U (1) 3–0–6
Historical development of weather prediction. Application of elementary kinematics and dynamics to patterns of atmospheric flow. Description of structure and behavior of cyclonic and anticyclonic circulation. Simple dynamical prediction models. Petterssen, *Weather Analysis and Forecasting*, Vol. I, 2nd ed. *Sanders*

19.44 *Synoptic Meteorology II*
Prereq.: 19.43, 19.601
Year: U (2) 3–0–6
Further study of dynamical prediction models, with emphasis on large-scale vertical motion, clouds, and precipitation. Stability and instability and their relation to weather phenomena. Structure and behavior of severe convective systems. Petterssen, *Weather Analysis and Forecasting*, Vol. II, 2nd ed. *Sanders*

19.45 *Synoptic Meteorology III* (A)
Prereq.: 19.44
Year: G (1) 3–0–6
Analysis of methods and results of investigations of cyclonic and anticyclonic behavior. Synthesis of this information into models and theories of pressure change. Review of recent research in synoptic meteorology. Interrelationships between surface and upper-air changes, their application to the forecast problem. *J. M. Austin*

19.46 *Numerical Weather Prediction* (A)
Prereq.: 18.05
Year: G (2) 3–0–6
Scale analysis of atmospheric motions and the problem of meteorological noise. The quasi-geostrophic forecast system. Finite difference methods and the analysis of computational stability. Deviation and study of some simple atmospheric models for numerical forecasting. *Phillips*

19.51 *Synoptic Laboratory I*
Prereq.: 19.02
Year: U (1) 0–15–0
Techniques of analysis and prognosis of the daily circulation pattern. Dynamical and empirical methods for prediction of the circulation pattern and associated weather phenomena. *Sanders*

19.53 *Synoptic Laboratory II* (A)
Prereq.: 19.44, 19.51
Year: G (2) 0–12–0
Theory and practice of modern weather prediction; development of quantitative prognostic procedures. *Sanders*

19.601 *Introduction to Theoretical Meteorology*
Prereq.: 8.02, 18.02
Year: U (1) 3–0–6
Simplified treatment of atmospheric statics, dynamics and thermodynamics designed to provide the theoretical background for synoptic meteorology and to prepare the student for more advanced subjects in dynamic meteorology. *Phillips*

19.62 *Dynamic Meteorology I*
Prereq.: 19.601
Year: U (2) 3–0–6
Hydrodynamic equations of motion. Streamlines and trajectories, circulation and vorticity, theory of atmospheric turbulence, its effects on the vertical distribution of wind and other meteorological elements. Energy transformations in the atmosphere. *Lorenz*

19.64 *Dynamic Meteorology II* (A)
Prereq.: 19.62
Year: G (1) 3–0–9
Large-scale atmospheric motions. Examination of recent theories of the general circulation. Research in the application of fluid mechanics to meteorology and oceanography. *Starr*

19.67 *Planetary Fluid Dynamics* (A)
Prereq.: 18.60
Year: G (2) 3–0–9
Discussion of fluid dynamical problems on the planetary scale with examples drawn from the atmosphere, the oceans and the interior of the earth. Convectively driven circulations in rotating systems and high-speed computational methods for the solution of the governing equations. *Charney*

19.70 *Elementary Physics of the Atmosphere*
Prereq.: 8.03, *18.02*
Year: U (1) 3–0–6
Treatment of atmospheric radiation, the ozone layer and the upper atmosphere, atmospheric electricity, atmospheric optics, propagation of sound in the atmosphere, and icing of aircraft. *Keily*

19.71 *Radar Meteorology* (A)
Prereq.: 8.03, 19.02
Year: G (2) 2–1–4
Elementary principles of radar and the techniques of storm detection. Brief discussion of microwave propagation. Analysis of the radar echo from precipitation. The potentialities of radar for the examination and measurement of precipitation processes. Lectures and laboratory work with operating radar systems. *P. M. Austin*

19.72 *Physical Meteorology* (A)
Prereq.: 8.04, 18.03
Year: G (2) 3–0–6
Advanced treatment of solar and thermal radiation, the atmospheric heat balance, the physics of condensation and precipitation and certain aspects of the physics of the high atmosphere. Extensive use of the current literature. *Houghton*

19.83T *Physical Oceanography*
Prereq.: 8.02, 18.04
Year: U (1) 3–0–6
Structure and physical properties of the oceans. Methods of measurement and an outline of the observational information. Dynamics of oceanic current systems. Wind currents, waves and tides. *Houghton*

19.84 *Dynamic Oceanography* (A)
Prereq.: 18.05, 19.601
Year: G (2) 3–0–6
Hydrodynamics of planetary fluid flow. Restatement of various principles of classic fluid mechanics in a form useful in oceanography with special emphasis on the Coriolis and other effects of the earth's rotation. Classic theories of Ekman and others for ocean currents, and the energy balance for the oceans. *Starr, Phillips*

19.89 *Special Problems in Oceanography* (A)
Prereq.: 19.83
Year: G (1, 2) *Arr.*
Reading, consultation, and original investigation on oceanographic problems. *Staff*

19.91 *Meteorological Seminar I* (A)
Prereq.: 19.44, 19.62
Year: G (1) 2–0–4
Weekly reviews and discussions by staff members and students of recent meteorological contributions in current periodicals and of original research. *Houghton*

19.911 ***Meteorological Seminar I*** **(A)**
Prereq.: 19.44, 19.62
Year: G (1) 1–0–2

19.912 ***Meteorological Seminar II*** **(A)**
Prereq.: 19.911
Year: G (2) 1–0–2
Same as 19.91. *Houghton*

19.94 ***Special Problems in Meteorology***
Prereq.: 19.02
Year: G (1 or 2) *Arr.*
Reading, consultation, and original investigation on meteorological problems. *Staff*

19.95 ***Special Problems in Meteorology*** **(A)**
Prereq.: 19.44, 19.62
Year: G (1 or 2) *Arr.*
Reading, consultation and original investigation on meteorological problems of more advanced nature than those in 19.94. *Staff*

20.
Nutrition, Food Science and Technology

20.00 ***Man's Food***
Prereq.: ——
Year: 1 (1) 3–0–3
Survey of the natural and cultivated sources of food for mankind from the viewpoint of production, transportation, processing, packaging and consumption. History of the foods of mankind through the ages; natural food resources; nutritional requirements of man; effects of geography on dietary patterns; food habits and fads; environment, soils and agriculture; plant and animal breeding; harvest, storage and distribution of food; international movement of food; food economics; agricultural economics; federal regulation of agriculture; food industry of the U. S.; food laws and regulations; science and engineering in food technology; population and the world food problem. *S. A. Miller*

20.11T ***Food Science and Technology***
Prereq.: 5.41, 5.61, 7.21T
Year: U (1) 3–4–6
Basic principles of food preservation including methods of conservation, changes occurring during processing to storage, and the control of enzymes and microörganisms. *J. T. R. Nickerson*

20.15T ***Food Engineering*** **(A)**
Prereq.: 2.602, 10.31
Year: G (2) 3–3–6
Fluidization of solids, crystallization, foam concentration, dehydration and consideration of the behavior of food materials based on their structure. The engineering science of unit operations in the food industry. *Charm*

20.20 ***Flavor Chemistry and Flavor Methodology*** **(A)**
Prereq.: 5.41, 20.11T, 20.32T
Year: G (2) 3–4–6
Chemistry of foods with particular reference to the compounds responsible for flavor and odor. Physical and chemical techniques for the separation, purification, and identification of these compounds. Consideration of the behavioral sciences with respect to evaluation of food acceptability. *Wick*

20.30 ***Basic Nutrition***
Prereq.: 7.05
Year: U (1) 3–0–5
Digestion and absorption of foodstuffs, metabolic functions of individual nutrients, nutritional requirements and interrelationships, and influence of environmental factors on metabolic processes. *Harper*

20.32T ***Principles of Food and Tissue Analysis*** **(A)**
Prereq.: 5.14, 5.41, 7.05
Year: G (1) 2–6–4
Basic principles of modern methods of analysis. Composition of foods and tissues. Determination of major and minor constituents of foods and tissues. *R. S. Harris*

20.36T ***Advanced Human Nutrition*** **(A)**
Prereq.: 20.30
Year: G (2) 4–0–6
Nutrient requirements of man; methodology and techniques of clinical investigation; evaluation of nutritional status and measurement of nutrient requirements; effects of dietary and conditioned nutrient deficiencies; nutrition in disease; effects of disease on nutritional status and nutrient requirements; age and nutrition. *Watkin*

20.37 ***Endocrinology*** **(A)**
Prereq.: 7.05, 7.06
Year: G (2) 2–0–4
Introduction to those nutritional problems requiring an understanding of endocrinology. Review of basic principles as well as recent advances, with an emphasis on the multi-disciplinary approach in nutritional research. *Fillios*

20.38T ***Factors Influencing the Nutritional Values of Foods*** **(A)**
Prereq.: 20.11T, 20.30
Year: G (1 or 2) 3–0–3
Factors which influence and determine the nutrient content of foods from plant and animal sources during agricultural production. Losses and gains in the nutritional values of foods and food products during transit, treatment, and storage. Discussion of the effects of the following operations: harvesting, transportation, refrigeration, freezing, concentration, dehydration, bleaching, blanching, refining, canning, pickling, salting, brewing, fermenting, baking, steaming, boiling, frying, roasting, toasting and storage of processed foods. Procedures for minimizing the destruction and inactivation of vitamins and amino acids in foods. The enrichment, restoration, and fortification of foods and food products with nutrients. *R. S. Harris*

20.40 ***Selected Topics in Nutrition and Food Science and Technology*** **(A)**
Prereq.: 20.11T, 20.30
Year: G (1 or 2) 3–0–4
Detailed discussion of selected topics of current interest. Class work in various fields of nutrition, food science and technology not covered by regular subjects of instruction. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

20.43T *Industrial Microbiology* (A)
Prereq.: 7.21T
Year: G (2) 3–6–4
Selected topics in the uses of microorganisms for the production of substances of industrial value. Detailed consideration of the biochemistry of fermentations. *Dunn*

20.46T *Food Microbiology* (A)
Prereq.: 7.05, 7.21T
Year: G (2) 3–6–6
Quantitative aspects of bacteriology and their application to food processing. Mathematical considerations of thermal destruction. *J. T. R. Nickerson*

20.47T *Biochemical Engineering* (A)
Prereq.: 7.21T, 10.13
Year: G (1 or 2) 3–6–4
Application of engineering sciences to fermentative changes produced by microorganisms. Consideration of the kinetics of fermentations as well as techniques for the separation, isolation, and recovery of the end products of the metabolism of microorganisms. Detailed consideration, at the enzymatic level, of the changes induced. *Mateles*

20.51T *Advanced Food Science and Technology* (A)
Prereq.: 2.602, 10.13, 20.11T
Year: G (1 or 2) 3–6–6
Consideration of food science and technology from the point of view of the basic chemistry of the raw materials, changes occurring during processing and storage, and integration of these processes through engineering operations. The role of the behavioral sciences and the sensory properties of the foods. *Goldblith, Karel*

20.57T *Food Applications of Ionizing Radiations* (A)
Prereq.: 8.04, 20.11T
Year: G (1) 3–4–6
Theory and application of ionizing energy to the preservation of foods. Consideration of the basic effects of radiations on microorganisms and on compounds of biological importance. Dosimetry of intense beams of high-energy radiations. (*Alternate years.*) *Goldblith*

20.59T *Food Additives and Contaminants* (A)
Prereq.: 20.11T, 20.30
Year: G (1 or 2) 3–6–4
Lectures and laboratory exercises devoted to modern food protection factors. Problems of compliance with government regulatory agencies and relationship of these agencies to the modern food and drug industries. Animal studies involving growth, metabolism, toxicology, pathology, and chemical and isotopic techniques. (*Not offered 1961–62.*) *Uram*

20.61 *Seminar in Nutrition, Food Science and Technology* (A)
Prereq.: ——
Year: G (1) 2–0–2
Presentation of recent advances in nutrition, food science and technology. *Staff*

20.62 *Seminar in Nutrition, Food Science and Technology* (A)
Prereq.: 20.61
Year: G (2) 2–0–2
Continuation of 20.61. *Staff*

20.71 *Research Problems* (A)
Prereq.: ——
Year: G (1) *Arr.*

20.72 *Research Problems* (A)
Prereq.: ——
Year: G (2) *Arr.*
Directed research in the field of nutrition and food science. *Staff*

20.81 *Public Health Nutrition* (A)
Prereq.: ——
Year: G (S) 12–0–4
Project visits and seminar discussions of such aspects of public health nutrition as the incorporation of nutrition into public health programs at international and local levels. Bilateral and international technical assistance programs involving nutrition. Nutrition services in departments of health. Integrated nutrition programs requiring the cooperation of ministries of health, education, and welfare. Application of supplementary feeding and food enrichment techniques. Nutritional factors in relation to growth and development, pregnancy and lactation, and cardio-vascular diseases. Interrelationship between infection and nutrition. Extension of dietary requirements for differing environmental and cultural situations. The role of physicians, nutritionists, nurses, teachers, home economists, agricultural extension personnel, and village leaders in the development of national nutritional programs. (*Restricted to physicians with an M.P.H. degree or its equivalent.*) *Scrimshaw*

20.82 *Clinical Nutrition* (A)
Prereq.: ——
Year: G (S) 9–0–4
Nine hours per week of round table discussions and three hours of hospital and clinic visits covering the characteristics, epidemiology, and prevention of nutritional diseases with special attention to protein malnutrition, kwashiorkor and marasmus, nutritional anemia, endemic goiter and vitamin deficiencies, and the relation of nutrition to morbidity and mortality from infectious diseases, cirrhosis of the liver, cardio-vascular diseases, and cancer. (*Restricted to physicians with an M.P.H. degree or its equivalent.*) *Scrimshaw*

20.83T *Evaluation of Nutritional Status* (A)
Prereq.: ——
Year: G (S) 2–10–4
Field trips twice weekly, in which an opportunity is given to become proficient in clinical examinations of different types of populations for the appraisal of nutritional status. Orientation in the use of biochemical methods and in the conduct of surveys and interviews to determine the dietary habits of families and individuals. Participants will have direct responsibilities for obtaining survey data and for its calculation, analysis, and interpretation. (*Restricted to physicians with an M.P.H. degree or its equivalent.*) *Scrimshaw*

20.85 *Research Management in the Food and Drug Industries* (A)
Prereq.: ——
Year: G (1) 2–0–2

20.86 *Research Management in the Food and Drug Industries* (A)
Prereq.: ——
Year: G (2) 2–0–2
Lectures devoted to laboratory management problems peculiar to the food and drug industries and to technological problems encountered in the production of specific foods and food by-products. Governmental regulatory agencies and their relationship to modern food and drug industries. Coordination of research personnel and facilities with the production and sales departments in connection with the development of specific food products. *C. N. Frey*

21.

Humanities

21.001 ***Philosophy and Scientific Methodology***
Prereq.: ——
Year: 1 (1) 2–0–4
Examination of the methods of science and of the philosophical problems which are raised by attempts to understand and justify these methods. Mathematical inference, observation, hypothesis, and confirmation. Problems of a priori knowledge, induction, the status of theoretical entities, and the relation between mind and matter. Implications of science for religion and ethics. *Katz*

21.002 ***English Composition***
Prereq.: ——
Year: 1 (1, 2) 2–0–4
Principles of effective written communication. Logical organization of papers, precise and coherent expression of facts and opinions. Several papers. *Stone*

21.003 ***Composition Workshop***
Prereq.: ——
Year: U (1, 2) *Arr.*
Workshop for any undergraduate having difficulty with written expression in either a humanities or a professional subject. Instruction by individual conferences, insofar as time permits. Criticism of samples of the student's writing for organization and style, as well as for errors in composition. Application, through practice and revision, of the principles of good writing to specific assignments in the student's field. Formal enrollment unnecessary, since no credit given. *Stone*

21.005 ***Public Speaking***
Prereq.: ——
Year: 1 (1,2) 3–0–3
Principles of effective oral communication. Instruction in the delivery, content and logical development of subject matter. Attention to the informative speech with individual training in the extemporaneous and impromptu speech situation. Practice and individual criticism to assist the engineer in his professional work and give him confidence in his speaking ability. When feasible, students interested in debating to be in a special section. *R. F. Smith*

21.01[1] ***Introduction to the Humanities***
Prereq.: ——
Year: 1 (1) 3–0–5

21.02[1] ***Introduction to the Humanities***
Prereq.: 21.01
Year: 1 (2) 3–0–5
Introduction to history, literature and philosophy through intensive reading and discussion of important works from classical, medieval and early modern periods; emphasis on method and structure as well as content. Training in writing through essays based on assigned readings. *Reiche*

21.03[1] ***Modern Western Ideas and Values***
Prereq.: 21.02
Year: U (1) 3–0–5

21.04[1] ***Modern Western Ideas and Values***
Prereq.: 21.03
Year: U (2) 3–0–5
Analysis of selected intellectual, ethical and aesthetic developments since the beginning of the Age of Reason. Readings in literary classics and in great books on religion, philosophy, science, and political economy. Second term: the period since the late nineteenth century. *Mazlish*

21.05 ***Humanities Senior Seminar***
Prereq.: ——
Year: U (1) 3–0–6
Lamson

21.06 ***Humanities Senior Seminar***
Prereq.: 21.05
Year: U (2) 1–0–4
Lamson

21.08 ***Scientific and Engineering Writing***
Prereq.: ——
Year: U (1, 2) 2–0–4
Instruction in the types of communications that scientists and engineers are called upon to write. Detailed analysis of the problems of conveying technical information to non-technical as well as to technical audiences. Preparation of a formal report as a term project; selection of topic from the student's professional subject or experience. *Rathbone*

LITERATURE[2]

21.11 ***Introduction to Literature***
Prereq.: ——
Year: U (1, 2) 3–0–5
Study of fiction, drama, and poetry as forms of art. Reading and discussion of works by such authors as Blake, Chekov, Conrad, Eliot, Faulkner, Kafka, Shaw, Dylan Thomas, Tennessee Williams. This subject prerequisite to further subjects in literature. *W. C. Greene*

21.12 ***Literary Criticism***
Prereq.: 21.11
Year: U (2) 3–0–5
Reading and discussion of samples of literature and criticism from several periods and nations. Main emphasis on the exploration of several key problems: the relationship of theory and practice, the problem of literary history, and the philosophy of criticism. *Kampf*

21.13 ***The Epic***
Prereq.: 21.11
Year: U (1) 3–0–5
Reading of such epics as the *Iliad*, the *Aeneid*, the *Mahabharata*, the *Volsungasaga*, *Beowulf*, the *Song of Roland*, *The Morte Darthur*, and *John Brown's Body;* discussion of their mythological and ritual backgrounds, their shaping and decoration, their meanings as documents and as examples of art. (*Not offered 1961–62.*) *W. C. Greene*

[1]Special sections with lectures and readings in French are conducted by the Department of Modern Languages. These are restricted to students with an adequate background in French.
[2]For other subjects in literature, see those listed under Modern Languages.

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

21.15T *Theatre Arts: Elementary Stagecraft and Production Studies*
Prereq.: 21.11
Year: U (1, 2) 3–0–5
Introduction to the techniques of the modern theatre as a means of realizing the thematic content of drama. Tutorial discussions and laboratory exercises in the theatre. Individual courses of study arranged with the instructor in advance, dealing with such subjects as production methods, organizational structure of the theatre, and history of theatre development. *Everingham*

21.16 *Tragedy and Modern Drama*
Prereq.: 21.11
Year: U (2) 3–0–5
Close reading study of non-comic drama from Sophocles to the present day. Historical background and theatre history. Plays by Aeschylus, Marlowe, Shakespeare, Ibsen, Shaw, O'Neill, Wilder, Hellman, Williams, Miller, and others. Approved practical projects in theatrical techniques accepted in lieu of term papers. *Everingham*

21.17 *Shakespeare*
Prereq.: 21.11
Year: U (1) 3–0–5
Reading and discussion of eleven major plays of Shakespeare. *N. N. Holland*

21.18 *Non-Western Literature*
Prereq.: 21.11
Year: U (2) 3–0–5
Reading of major classics and contemporary pieces, largely from India, China, and Japan. Some illustration of attitudes toward life and art of these nations by use of visual art, and reference to religious and philosophical systems. (*Not offered 1961–62.*) *W. C. Greene*

21.19T *Major Writers of the English Renaissance*
Prereq.: 21.11
Year: U (1) 3–0–5
Study of selected works by Marlowe, Spenser, Shakespeare, Jonson, Bacon, Donne, Browne, and Milton in relation to literary traditions and to philosophical and scientific ideas in the Renaissance. *Lamson*

21.20 *The Bible*
Prereq.: 21.11
Year: U (2) 3–0–5
Close reading of seminal texts from Old Testament and New Testament as literary documents illustrating specific kinds of religious experience. Philosophical implications and historical repercussions of such basic problems as faith, creation, perfection, time, etc. *Reiche*

21.21 *Dostoevsky, Tolstoi and Modern Russian Literature*
Prereq.: 21.11
Year: U (1) 3–0–5
Major emphasis on Dostoevsky and Tolstoi. Additional readings (varying somewhat from year to year) from such writers as Pushkin, Gogol, Aksakov, Turgenev, Leskov, Chekhov, Bunin, Gorky, Blok, Olyesha, Pasternak. All works in translation. *MacMaster*

21.22 *The Nature of Poetry*
Prereq.: 21.11
Year: U (2) 3–0–5
Aims to stimulate understanding and appreciation of essentials of poetry. Selected works of poets from Chaucer to contemporary Americans discussed in terms of the variety of influences — social, psychological, literary, technical — shaping them. Lectures, readings, and informal discussions by poets in the vicinity. *T. Wood*

21.23 *Modern Poetry*
Prereq.: 21.11
Year: U (1) 3–0–5
After an examination of general poetic aims and methods, discussion of Yeats, Frost, Pound, Eliot, Stevens, Williams, Cummings, and certain younger poets. *Weiss*

21.24 *The Nature of the Comic*
Prereq.: 21.11
Year: U (2) 3–0–5
Close reading of comic works by such writers as Apuleius, Cervantes, Chaucer, Chekhov, Carroll, Moliere, and Shaw, with discussion of theories of the comic, including Bergson's, Freud's, and Kierkegaard's. *N. N. Holland*

21.25 *The Modern Novel*
Prereq.: 21.11
Year: U (2) 3–0–5
Discussion of works by such novelists as Kafka, Hesse, Joyce, Mann, Faulkner, Camus, Golding, Amis, Robbe-Grillet. *C. Collins*

21.26T *English and Continental Literature of the Nineteenth Century*
Prereq.: 21.11
Year: U (2) 3–0–5
Reading of selected works by some major writers of England and the Continent against the background of pertinent artistic and social movements and of philosophical ideas. Consideration of relationship of the works read to twentieth-century literature. Authors chosen for 1961–62: Coleridge, Goethe, Stendhal, Dickens, Tennyson, Hopkins, Shaw, and Conrad. *Lamson*

21.27 *The Short Novel*
Prereq.: 21.11
Year: U (1) 3–0–5
Demonstration of the range, variety, formal and technical characteristics of the genre by study of such writers as Tolstoi, Dostoevsky, Melville, Flaubert, Kafka, Mann, Joyce, Conrad, James, Lawrence, Hemingway and Faulkner. *Weiss*

21.29 *Eighteenth-Century Literature*
Prereq.: 21.11
Year: U (1) 3–0–5
Reading and discussion of the poetry and prose of Swift, Pope, Addison, Shaftesbury, Dr. Johnson, Voltaire, Diderot, etc. Discussion of these authors in the context of eighteenth-century thought. *Kampf*

21.31 *American Folklore*
Prereq.: 21.11
Year: U (1) 3–0–5
American folklore as historical documentation which, in a vital and dramatic way, illustrates the personal beliefs and experiences of our people. An extensive survey of our lore by geographical area and historical era with an examination of diaries and letters, histories like Parkman's *Oregon Trail*, DeVoto's *Across the Wide Missouri*, and fiction like A. B. Guthrie's *The Way West*. Use of folk material in cultivated music, drama, literature, and art. *T. Wood*

21.33 *Literature and Society*
Prereq.: 21.11
Year: U (1) 3–0–5
Discussion of a few writers as exemplars of the mores and aesthetics which produced them. A choice each semester of writers from the Middle Ages to the present who are not ordinarily treated in other literature subjects. Choice from such authors as Chaucer, Marlowe, Moliere, Pope, Fielding, Schiller, Coleridge, Balzac, Baudelaire, Hawthorne, Melville, Twain, Hardy, Lawrence, Mann, O'Neill. Each student to make independent study of one author of his own choice. *C. F. Hoffman*

21.34 *Modern American Literature*
Prereq.: 21.11
Year: U (2) 3–0–5
Discussion of works by such writers as Eliot, Pound, Hemingway, Fitzgerald, Faulkner, Stevens, Williams, Cummings, Nathanael West, Capote, Salinger, Kerouac, Levertov, Ginsberg, Bellow, and Robert Lowell. *C. Collins*

21.391 *Special Topics in Literature*
Prereq.: Any two subjects in literature
Year: U (1) 3–0–5
Topics in literature not included in other subjects. *Staff*

21.392 *Special Topics in Literature*
Prereq.: Any two subjects in literature
Year: U (2) 3–0–5
Topics in literature not included in other subjects. *Staff*

HISTORY

21.41 *The United States: Making of the Nation, 1760–1865*
Prereq.: 21.04
Year: U (1) 3–0–5
An examination of the formation and initial growth of the nation. Description and analysis of the coming of independence, the expansion west, the continuing conflict over slavery, and other basic developments for which the political story provides the primary chronological framework. *Chandler*

21.42 *The United States: Industrial and World Power, 1865–1960*
Prereq.: 21.04
Year: U (2) 3–0–5
Study of the nation's responses, particularly in the area of political action, to rapid industrialization and urbanization and to the country's expanding role as a major world power. *Jensen*

21.43 *American Economic History*
Prereq.: 21.04
Year: U (1) 3–0–5
Transformation of the American economy from a rural, agrarian to an industrial, urban one. Analysis of the interaction of such factors as natural resources, capital, labor, markets, technology, and entrepreneurships, by focusing on such dynamic forces as westward expansion, the coming of the railroads, the national market, the new generators of power, and the application of science to industry. *Chandler*

21.44 *Economic Leadership in the Industrial World*
Prereq.: 21.04
Year: U (2) 3–0–5
Historical, analytical, and comparative study of a leading economic and social group. A study of the historical development of business leaders in the United States, analyses of their current activities, and a comparison of American entrepreneurs with those in other societies and economies. (*Not offered 1961–62.*) *Chandler*

21.46 *American Intellectual History*
Prereq.: 21.04
Year: U (2) 3–0–5
Examination of classical works in the development of American thought; emphasis on religious, social and political consciousness of such significant American thinkers as Edwards, Franklin, Jefferson, Emerson, Thoreau, Calhoun, James, Veblen, and Niebuhr. *Hartley*

21.48 *Technology and Economic Growth*
Prereq.: 21.04
Year: U (2) 3–0–5
Growth of technology in the modern world in its relationship to economic and social change. Crafts technology; industrialization — invention, origins of mass production and interchangeable parts, power sources, transportation, mechanization of agriculture; technology and large-scale enterprise, new industries. *Woodbury*

21.51 *Modern Europe, 1500–1815*
Prereq.: 21.04
Year: U (1) 3–0–5
Study of the forces that brought about the transformation of Europe from a feudal, agrarian, and theologically oriented society to one characterized by capitalism, the nation state, and secular ideals. Attempt to study this as a unified change, but with due attention to opposing trends and contradictions; organization of classroom work around major topics such as the Reformation, capitalism, the scientific revolution, and the French Revolution. *Niehaus*

21.52 *Modern Europe, 1815–1960*
Prereq.: 21.04
Year: U (2) 3–0–5
Failure of the alliance system; nationalism; liberalism; the acceleration of the Industrial Revolution; modern imperialism; the alliance systems; the arms race; exaggerated nationalism; pre-1914 cultural aspects; World War I and the treaties; the decline of the West; Fascism; Communism; World War II and its aftermath. *Shenton*

21.53 *The Revolt of Asia*
Prereq.: 21.04
Year: U (1) 3–0–5
Emphasis on an examination of selected contemporary Oriental revolutions, notably the Chinese Revolution. The traditional cultures, their geographical settings, the impact of the West, and the resulting breakdown of the self-sufficiency and culture of these countries as a background for the recent successful revolutions. (*Not offered 1961–62.*) *Mahoney*

21.54 *Russian Revolution and the Soviet Union*
Prereq.: 21.04
Year: U (2) 3–0–5
Nature and meaning of the Soviet challenge to America. Use of historical and intellectual materials in the study of the origins and course of the revolution. Political, social, and economic structure of the USSR and its relationship to recent and contemporary Soviet foreign policy. *MacMaster*

21.55 *History of Engineering*
Prereq.: 21.04
Year: U (1) 3–0–5
History of the techniques and achievements in engineering from ancient times to about 1800. The goals, methods, and status of the engineer in Babylonia, Egypt, Greece, Rome, the Arabic world, the Middle Ages, and the Renaissance set against the background of the political, social, and economic conditions of the times. Study of the development of engineering as an integral part of the life of cultures different from our own to give perspective and background for studying and evaluating the position and contributions of the engineer in modern times. Extensive use of lantern slides. *Woodbury*

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21.56 *History of Engineering*
Prereq.: 21.04
Year: U (2) 3–0–5
Study of the development of modern engineering from 1800 to about 1930. Presentation of engineering advance as an important factor among the economic and social changes which center around the Industrial Revolution. Concentration on those key aspects of greatest importance for future engineering development and for economic and social change — coal, steel, textiles, machinery, transportation, electric power, and others. Use of lantern slides. *Woodbury*

21.58 *Problems in Modern Intellectual History: Freud*
Prereq.: 21.04
Year: U (2) 3–0–5
Detailed examination of the treatment by a crucial thinker of major questions in the nineteenth and twentieth centuries. Development and application of techniques useful for the interpretation of any writer. Stress on understanding the content and development of Freud's thought, not on evaluating his work. Reading and discussion of original sources; papers. *Schoenwald*

21.591 *Special Topics in History*
Prereq.: Any two subjects in history
Year: U (1) 3–0–5
Topics in history not included in other subjects. *Staff*

21.592 *Special Topics in History*
Prereq.: Any two subjects in history
Year: U (2) 3–0–5
Topics in history not included in other subjects. *Staff*

PHILOSOPHY

21.61 *Philosophical Problems and Systems I*
Prereq.: 21.04
Year: U (1) 3–0–5
Study of central problems in the writings of selected philosophers from Plato to Kant. Readings in Plato's *Gorgias* and *Theaetetus*, Descartes' *Meditations* and *Discourse on Method*, Hume's *Treatise on Human Nature;* and from one to three of the following: Aristotle's *Metaphysics* and *Ethics*, Locke's *Essay Concerning Human Understanding*, Berkeley's *Principles of Human Knowledge*, Leibnitz's *Monadology*, and Kant's *Critique of Pure Reason*. *Rawls*

21.62 *Philosophical Problems and Systems II*
Prereq.: 21.04
Year: U (2) 3–0–5
Study of central problems in the writings of selected modern philosophers. Readings in Mill's *Utilitarianism* or *Theism;* Hegel's *Preface to the Phenomenology of Mind;* Russell's *Our Knowledge of the External World* or Ayer's *Language, Truth and Logic;* Wittgenstein's *The Blue and Brown Book;* and Kierkegaard's *Philosophical Fragments* and/or Dewey's *Quest for Certainty*. *Todes*

21.63T *History of Philosophy: Ethics*
Prereq.: 21.04
Year: U (1) 3–0–5
Historical study of writings by Plato, Aristotle, Hobbes, Butler, Hume, Kant, Bentham, J. S. Mill, and others in the field of moral philosophy. (*Not offered 1961–62.*) *I. Singer*

21.65 *Classical Philosophy*
Prereq.: 21.04
Year: U (1) 3–0–5
Selected readings in the pre-Socratics; in Plato and Aristotle; or in Hellenistic and later thought: Stoicism — Lucretius, Epictetus, and Marcus Aurelius; Epicureanism — Epicurus and Lucretius; Neo-Platonism — Plotinus and the critical encounter with early Christianity in theologians like Origen and Augustine; the development of the Logos-concept. *Reiche*

21.67 *Philosophies and Religions of the East*
Prereq.: 21.04
Year: U (1) 3–0–5
Exploration of the distinctive perspectives of India and the Orient on the nature of the universe, the goal of human life, and the means by which this goal is to be achieved. Reading and discussion on the basic texts of Hinduism, Buddhism, Confucianism, Taoism and Japanese Zen; lectures on historical background. *H. C. Smith*

21.68 *Major Religions of the West*
Prereq.: 21.04
Year: U (2) 3–0–5
Religious heritage of the Near East and West: Judaism, Christianity, Islam, and the ways of life they advocate; how they began and got their scriptures; men who founded and shaped them; developments in their theologies over the centuries; the chief differences between them. *H. C. Smith*

21.69T *Symbolic Logic*
Prereq.: 21.04
Year: U (1) 3–0–5
Introduction to the principles of deductive logic. The major results concerning the structure of mathematics. The place of modern logic in philosophy; its influence on the formulation of philosophical problems and on the search for methods for their solution. *Chomsky*

20.70T *Moral Philosophy*
Prereq.: 21.04
Year: U (2) 3–0–5
Systematic study of some of the main problems of moral philosophy. Special attention to intuitionism, idealism, and utilitarianism as moral theories, and to ethical relativism and moral scepticism. Readings from the leading writers of the twentieth century. *Rawls*

21.71 *Philosophy of History*
Prereq.: 21.04
Year: U (2) 3–0–5
Examination of the nature of historical thought, and study of the transition from mythical to logical treatment of the past. Theories and philosophies of history of such thinkers as Vico, Condorcet, Kant, Hegel, Comte, Marx, Ranke, Acton, Burckhardt, Spengler, Ortega y Gasset, Toynbee, and Freud. Extrapolation from the philosophy of history to the general philosophy of the cultural sciences. *Mazlish*

21.72 *Philosophy in Literature*
Prereq.: Any two 21 subjects above 21.04
Year: U (2) 3–0–5
Study of philosophical ideas in great works of literature. Particular emphasis upon philosophical problems related to the concept of love and the nature of feeling. The views of Plato, St. Paul, St. Augustine, Stendhal, Freud, etc. studied both in themselves and as means of understanding books such as *Tristan and Iseult, Swann's Way, The Kreutzer Sonata, Lady Chatterley's Lover*, etc. (*Not offered 1961–62.*) *I. Singer*

21.73 *Philosophy of the Arts*
Prereq.: 21.04
Year: U (1) 3–0–5
Nature of art and beauty, particularly problems about the creative process, analysis of a work of art, the aesthetic experience, and standards of evaluation. These and related problems studied both in themselves and in terms of their treatment in the history of aesthetics. (*Not offered 1961–62.*) *I. Singer*

21.74 *Metaphysics*
Prereq.: 21.61 or 21.62
Year: U (2) 3–0–5
Nature of the metaphysical quest in the light of recent criticisms thereof, leading into an examination of six classic world views: realism, mechanism, naturalism, Whitehead's philosophy of organism, idealism and mysticism. *H. C. Smith*

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21.76T *Problems in Contemporary Philosophy*
Prereq.: 21.04
Year: U (2) 3–0–5
Main currents in twentieth-century empiricist philosophy. Rise and growth of the analytic, logical positivist and pragmatist movements and their offshoots. Impact of science, mathematics and symbolic logic; rejection of metaphysics; attempt to construct a scientific philosophy whose tasks are clarification, reconstruction, and logical analysis of ordinary and scientific language. The views of Peirce, Moore, Russell, Wittgenstein, Carnap and the Vienna Circle, and other analytic philosophers concerning problems in the theory of language (meaning, existence, verifiability), the theory of knowledge (a priori and empirical truth, reductionism, causality and induction), ethics and the broader role of technical philosophy. (*Not offered 1961–62.*) *Chomsky*

21.77 *History of Political and Social Thought*
Prereq.: 21.04
Year: U (1) 3–0–5
An examination of the philosophical and moral ideas and conceptions of society in a number of historical texts such as Aristotle, *Politics;* the treatise on law in the *Summa Theologica* of St. Thomas Aquinas; Hobbes, *Leviathan;* Rousseau, *Social Contract;* Bentham, *Principles of Morals and Legislation;* Hegel, *Philosophy of Right;* Marx, parts of *German Ideology* and *Economic and Philosophic Manuscripts of 1844;* and Mill, *On Liberty.* *Rawls*

21.78 *Political and Social Philosophy*
Prereq.: 21.04
Year: U (2) 3–0–5
A systematic study of some of the main philosophical concepts and moral principles associated with such conceptions as natural law and natural rights, justice and equality, liberty and toleration, the common good and social utility. An attempt to relate these concepts and principles to political and social theory. *Rawls*

21.79 *Nature of Man*
Prereq.: 21.04
Year: U (1) 3–0–5
Examination, comparison, and evaluation of leading contemporary views, with special attention to the Freudian, Behaviorist, Marxist, Existentialist, Thomist, and Oriental. (*Not offered 1961–62.*) *H. C. Smith*

21.80 *Existentialism*
Prereq.: 21.04
Year: U (2) 3–0–5
An attempt to discover and elaborate the fundamental existential insight through a study of the ethical, theological, and metaphysical views of Kierkegaard, Heidegger, Sartre, Dostoevsky, and Marcel. Analysis and discussion of the existentialist contribution to the problems of consciousness, time, the body, other minds, objectivity, and truth. *H. L. Dreyfus*

21.81 *Science and Philosophy from Antiquity to Copernicus*
Prereq.: 21.04
Year: U (1) 3–0–5
The course of civilization around the growth of scientific ideas. Philosophical ideas accompanying the formation of scientific concepts, from the Pre-Socratics and later Greek developments through the medieval view to its breakup in the Renaissance under the influence of Copernicus and the age of discoveries. *de Santillana*

21.82 *Science and Philosophy from Copernicus to the Present*
Prereq.: 21.81
Year: U (2) 3–0–5
Continuation of 21.81 to modern times. The period from the Scientific Revolution and the founding of modern scientific thought to the present. The formation of the main scientific ideas, their philosophical implications, and the interactions of science and society. *de Santillana*

21.83 *Philosophy of Science*
Prereq.: Any two 21 subjects above 21.40
Year: U (1) 3–0–5
Discussion of epistemological problems arising in the natural sciences: foundations of geometry; the hypothetico-deductive method; induction and statistical inference; perceptual data and physical reality; the relations between micro- and macro-physics; science and metaphysical speculation. *R. S. Cohen*

21.84 *Topics in the History and Philosophy of Science*
Prereq.: Any two 21 subjects above 21.40
Year: U (2) 3–0–5
Consideration of philosophical problems concerning space, time, matter, cause, and chance in the light of some of the discoveries of modern physics. (*It is strongly suggested that students have taken 8.05 and 8.06 or their equivalents. Not offered 1961–62.*)

21.85 *Cosmology — Old and New Problems*
Prereq.: 21.04
Year: U (1) 3–0–5
Cosmology in early times as the one total science. Its foundations in archaic astronomy. Its transformation under the influence of physics. The cosmological crisis in the eighteenth century. Modern cosmology as the convergence of all the sciences. Unsolved problems. *de Santillana*

21.86 *Problems of Modern Science in the Historical Perspective*
Prereq.: 21.04
Year: U (2) 3–0–5
Discussion of fundamental problems of science, mainly of the nineteenth century: matter and energy, field physics, evolutionary biology. Their origin, historic development, and present status. *de Santillana*

21.891 *Special Topics in Philosophy*
Prereq.: Any two subjects in philosophy
Year: U (1) 3–0–5
Topics in philosophy not included in other subjects. *Staff*

21.892 *Special Topics in Philosophy*
Prereq.: Any two subjects in philosophy
Year: U (2) 3–0–5
Topics in philosophy not included in other subjects. *Staff*

(A) indicates a subject given primarily for graduate students. (R) indicates a subject restricted to special groups because of content. Other notations are described on the first page of this Section.

MUSIC

21.91 ***Introduction to Music***
Prereq.: ——
Year: U (1, 2) 3–0–5
A subject to familiarize students who have little or no knowledge of music with the language of music and its universal literature. Rudiments of harmony and ear-training, and terminology of music. Analysis of representative masterworks through lectures and demonstrations. Listening to recordings, weekly exercises, and readings required. *G. Tucker, Mattfeld*

21.92 ***Western Music from the Middle Ages to the Baroque***
Prereq.: 21.91
Year: U (1, 2) 3–0–5
Study of representative composers in their historic perspective with emphasis on outstanding examples of masterworks of the Middle Ages, Renaissance, and Baroque. Detailed analysis of compositions by Bach. Listening to recordings, weekly exercises, and readings required. *Liepmann, G. Tucker*

21.93 ***Western Music in the Classic Era***
Prereq.: 21.91 or 21.92
Year: U (1) 3–0–5
Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterworks of the Classic era. Listening to recordings, weekly exercises, and readings required.
Liepmann, Mattfeld

21.94 ***Western Music in the Romantic Era***
Prereq.: 21.91 or 21.92
Year: U (2) 3–0–5
Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterworks of the Romantic era. Listening to recordings, weekly exercises, and readings required.
Liepmann, Mattfeld

21.95 ***Twentieth Century Music***
Prereq.: 21.93 or 21.94
Year: U (1) 3–0–5
Study of principal works by masters of twentieth century. Tradition and innovation as exemplified in the music of Schönberg, Stravinsky, Bartok, Hindemith, Copland, Ives, Prokofieff, Honegger, and other composers. The interrelationship of art music, folk music and popular music. Concerts, recordings, and discussion. (*Permission of instructor required.*) *G. Tucker*

21.96 ***The String Quartets of Beethoven***
Prereq.: 21.92
Year: U (2) 3–0–5
Detailed analysis of the quartets of Beethoven. Rudiments of score reading. Concerts, recordings, and discussion. (*Permission of instructor required.*) *Liepmann*

21.98 ***The Opera***
Prereq.: 21.92
Year: U (2) 3–0–5
Study of the nature and development of the music drama. Illustrations at the piano as well as from recordings. (*Not offered 1961–62.*) *G. Tucker*

22.
Nuclear Engineering

22.01 ***Engineering Practice School at Oak Ridge* (A)**
Prereq.: ——
Year: G (1, 2) 0–16–0

22.02 ***Engineering Practice School at Oak Ridge* (A)**
Prereq.: 22.01
Year: G (1, 2) 0–16–0

22.03 ***Engineering Practice School at Oak Ridge* (A)**
Prereq.: 22.02
Year: G (1, 2) 0–16–0
The Engineering Practice School at Oak Ridge, Tennessee — in the Diffusion Plant, the Electromagnetic Plant, and the Oak Ridge National Laboratory of the Atomic Energy Commission, all operated by Union Carbide Nuclear Company — is available for qualified graduate students in any department who are United States citizens, subject to security clearance by the Atomic Energy Commission. Under the direction of Institute faculty residing at Oak Ridge, the work will emphasize the application of engineering principles to the solution of plant problems and is designed to develop initiative, resourcefulness, and cooperative effort in large-scale industrial operations. These subjects are offered twice during the year — in the fall term, and again in the spring term. Each series carries academic credit for 48 units. Application should be made 3 to 4 months in advance to allow ample time for clearance. *Reid*

22.10 ***Elementary Nuclear Physics***
Prereq.: 8.04 or 8.041; 18.04
Year: G (1) 2–0–4
Introduction to aspects of modern physics important in nuclear engineering; atomic structure, atomic radiations and X-rays; nuclear structure, radioactivity, nuclear reactions, and the fission process. Primarily for students without prior knowledge of nuclear physics who wish background as preparation for 22.21. Students planning to take graduate work in nuclear engineering should take 8.051. *Kaplan*

22.20 ***Biological Effects of Nuclear Radiation* (A)**
Prereq.: 8.053 or 8.055 or 22.10
Year: G (2) 3–0–6
Review of interactions of nuclear radiations with matter and the effects of energy absorbed from nuclear radiation on simple and complex chemical systems, various organisms, and living tissue. Theories of the action of radiations on living matter, and considerations of various factors which affect the biological response, such as time and type of radiation. Theory and practice of radiation dosimetry with special reference to practical applications. Discussion of biological and physical bases for safety standards. *Brownell*

22.21 ***Nuclear Reactor Physics I*** **(A)**
Prereq.: 8.053 or 8.055 or 22.10; *18.06*
Year: G (1, 2) 3–0–9
Introduction to problems of fission reactor physics; nuclear reactions induced by neutrons; nuclear fission; diffusion and slowing-down of neutrons; elementary diffusion, age-diffusion and multigroup treatment of unreflected homogeneous reactors; reflected thermal reactors; heterogeneous reactors; reactor design parameters. Emphasis on the nuclear physical bases of reactor design and their relation to reactor engineering problems. *Benedict, Kaplan*

22.22 ***Nuclear Reactor Physics II*** **(A)**
Prereq.: 22.21
Year: G (2) 3–0–9
Problems relating to the operation of a nuclear reactor at power; poisoning effects of fission products; effect of temperature on reactor design parameters; excess reactivity; elements of reactor kinetics, perturbation theory, transport theory and control rod theory. Emphasis on applying reactor theory to actual reactor systems. *Fenech*

22.23 ***Nuclear Reactor Engineering*** **(A)**
Prereq.: 2.43 or 2.50 or 2.58 or 10.31; 22.21
Year: G (1, 2) 3–0–9
Engineering problems of nuclear reactors: including the production, transfer, and utilization of heat; thermal stresses; materials employed; change of reactivity with fuel irradiation; fuel cycles; shielding; power plant thermodynamics; and optimization of reactor systems. Application of information developed in 22.21 and 22.23 to a design project dealing with the steady state characteristics of a particular nuclear reactor. *Fenech, K. F. Hansen*

22.241 ***Principles of Control Systems*** **(A)**
Prereq.: 8.03, 18.04
Year: G (1) 3–0–6
Problem of control of dynamical systems and its implications, Fourier and Laplace transforms, transfer functions, feedback systems, flow graphs, block diagrams, transient and steady state response of feedback systems, stability criteria. Correlation techniques used in linear systems. Discussion of nonlinear problems. (*Not offered 1961–62.*) *Gyftopoulos*

22.242 ***Nuclear Plant Dynamics*** **(A)**
Prereq.: 6.213 or 6.601 or 22.241; 22.21
Year: G (2) 3–0–9
Nuclear reactor kinetics, thermal dynamics, inherent feedback loops, external control loops, transient and steady state performance of nuclear reactors. Pile statistics, pile oscillation tests. Dynamics of nuclear plants, analog and digital methods of analysis of nuclear systems. Analysis of nonlinear nuclear plant dynamics, development of boundedness and stability criteria for nonlinear systems. Synthesis of control systems. (*Not offered 1961–62.*) *Gyftopoulos*

22.25T ***Selected Topics in Reactor Physics*** **(A)**
Prereq.: 22.22
Year: G (1) 3–0–6
Recent advances in the physics of thermal neutron reactors: resonance capture, thermal flux distribution, fast fission effect; neutron energy spectra and thermalization; water-moderated reactors; physics of intermediate and fast reactors. *Kaplan*

22.26 ***Nuclear Reactor Design*** **(A)**
Prereq.: 22.22 or 22.242; 22.23
Year: G (2) 2–4–6
Systems analysis and design of nuclear reactors, integrating the requirements of reactor physics, control, heat transfer, safety, materials, power production, and fuel cycle management; economic optimization; computer applications; group design project. *E. A. Mason*

22.31 ***Nuclear Chemical Engineering*** **(A)**
Prereq.: 10.32
Year: G (1) 3–0–9
Applications of chemical engineering to the processing of materials for and from nuclear reactors. Fuel cycles for nuclear reactors; chemistry of uranium, plutonium and fission products; refining of uranium; production of materials for nuclear reactors; separation of products of nuclear reactors; inorganic solvent extraction as applied to nuclear reactor materials; disposal of radioactive wastes; processes for isotope separation; and theory of isotope separation. *E. A. Mason*

22.41 ***Nuclear Reactor Physics Laboratory*** **(A)**
Prereq.: 22.21
Year: G (1, 2) 2–6–4
Properties of the particles and radiations resulting from the fission process. Use of scintillation counters, ionization chambers, proportional counters, Geiger counters, health physics instruments, and other detection devices employed in reactor technology. Experimental methods for determining the macroscopic properties of nuclear reactors, including cross section measurements, cadmium ratios, diffusion lengths, albedoes, Fermi age, and neutron multiplication of the subcritical assembly Radioactive chemical separation methods. *Rasmussen*

22.411 ***Nuclear Reactor Physics Laboratory*** **(A)**
Prereq.: 8.532, 8.59, 22.21
Year: G (1, 2) 0–6–0
Laboratory aspects of 22.41. (*Restricted to selected officers of the U. S. Navy.*) *Rasmussen*

22.42 ***Nuclear Reactor Laboratory*** **(A)**
Prereq.: 22.41
Year: G (1, 2) 2–6–4
Techniques of nuclear reactor operation, reactivity evaluation, critical mass determination, shielding surveys, reactivity effect measurements, power measurements. Techniques and experiments utilizing the M.I.T. reactor as a neutron and gamma ray source including selections from experiments on shielding, neutron flux, neutron spectrum, reactor parameters, neutron temperature measurements, gamma ray spectrum, pile neutron temperatures and cross sections. Building and use of such equipment as shielding test facilities, pile oscillators, a neutron spectrometer, time of flight equipment, and mechanical velocity selector. *Thompson*

22.51 ***Neutral Particle Transport I*** **(A)**
Prereq.: 8.791; or 18.15 and 22.21; or 18.28
Year: G (2) 3–0–9
Boltzmann and integral transport equations. Adjoint solutions. Infinite medium problem. Spherical harmonic and variational methods. Kinetics. Perturbation theory. Corrections to diffusion theory. (*Alternate years. Not offered 1961–62.*)

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22.52 ***Neutral Particle Transport II*** **(A)**
Prereq.: 8.791; or 18.15 and 22.21; or 18.28
Year: G (2) 3–0–9
Milne problem. Slowing down theory. Serber-Wilson and Feynman-Welton methods. Thermalization. Special methods of solving Boltzmann and integral transport equations. Fundamental shielding theory. (*Alternate ears.*) *Dupree*

22.53 ***Digital Computers in Nuclear Engineering*** **(A)**
Prereq.: 18.04, 22.21
Year: G (1) 3–0–6
Applications of digital computers to nuclear engineering problems. Computers. Assembly, diagnostic, and other subroutines. Real time simulation. S_n method. Monte Carlo method. Methods of differencing. Stability. Extrapolation. Fuel cycles, reactor control, kinetics, heat transfer. *K. F. Hansen*

22.61 ***Introduction to Thermonuclear Processes*** **(A)**
Prereq.: 8.053 or 8.055 or 8.05 or 22.10
Year: G (1) 3–0–9
Survey of the means of obtaining energy from fusion reactions. Energy resources. Atomic and electronic collision phenomena, and transport and electromagnetic theory applicable to confined plasmas. Methods of producing and heating plasmas. Electromagnetic methods of confinement. Material and energy loss processes. Energy balances. Recent experiments. Diagnostics. *Gyftopoulos*

22.62 ***Thermonuclear Processes*** **(A)**
Prereq.: 6.322 or 8.72; 8.231 or 22.61
Year: G (2) 3–0–9
Topics in plasma dynamics of current interest in thermonuclear research, such as: conductivity of highly ionized plasma; radiation losses; wave propagation; magnetic field structures; instabilities; dynamics of a thermonuclear system; critical review of confinement schemes; advanced diagnostic techniques; methods of reducing impurities. *Rose*

22.63 ***Engineering Physics of Plasma and Particle Devices*** **(A)**
Prereq.: 22.41, 22.61
Year: G (1) *Arr.*
Engineering physics concepts involved in the design, control, operation, and maintenance of modern experimental systems. Normally conducting and superconducting magnetic systems; vacuum systems; mechanical structures; other topics of interest. Examples from recent practice; class design project. *Rose, Thompson*

22.64 ***Plasma Kinetic Theory*** **(A)**
Prereq.: 8.07, 18.15T
Year: G (2) 3–0–6
Many-body problem with Coulomb interactions. Random processes, Fokker Planck equation, development of intuitive concepts. Integrated Liouville equation, particle correlations, survey of recent theoretical methods. Derivation of fluid equations, the Vlasov equation, plasma oscillations, instabilities, Landau damping. Thermalization. *Dupree*

22.71 ***Materials for Nuclear Reactors*** **(A)**
Prereq.: 22.21
Year: G (2) 2–0–6
Selection of materials for fuel, cladding, coolant, moderator, controls, and structures in different reactor types. Limitations on material use in reactors based on mechanical and thermal properties, corrosion and radiation effects. Economic and engineering considerations in selection and fabrication of materials, with specific example of uranium dioxide fuel. *Chernock*

22.90 ***Special Problems in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: 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. *E. A. Mason*

22.91 ***Seminar in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: G (1) 2–0–1

22.92 ***Seminar in Nuclear Engineering*** **(A)**
Prereq.: ——
Year: G (2) 2–0–1
For graduate students engaged on doctoral theses. *Benedict*

23.
Modern Languages

23.11 ***Elementary German***
Prereq.: ——
Year: U (1) 3–0–5

23.12 ***Elementary German***
Pre.: 23.11
Year: U (2) 3–0–5
Necessary foundation in German language for conversational and literary purposes. Training in pronunciation, elementary grammar, acquisition of useful vocabulary, reading of varied matter. *Klima*

23.13 ***Intermediate German***
Prereq.: 23.12 or 2 years high school German
Year: U (1) 3–0–5
Continuation of practice in spoken and written German. Training in pronunciation and grammar, acquisition of useful vocabulary and idiomatic expressions. Conducted primarily in German. *Kirshner*

23.14T ***Intermediate German***
Prereq.: 23.13
Year: U (2) 3–0–5
Introduction to German literature. Reading, translation and discussion of works of nineteenth and twentieth century German authors. Introduction to the vocabulary of literary and cultural criticism. Conducted in German. *Kirshner*

23.15T *The Romantic Era and Nineteenth Century Realism*
Prereq.: 23.14T
Year: U (1) 3–0–5
The evolution of German opinion and life as seen in the works of romantic and realistic German writers. Conducted in German. (*Not offered 1961–62.*) *Bon*

23.16T *Naturalism, Expressionism — Era of the Great Novel*
Prereq.: 23.14T
Year: U (2) 3–0–5
Selected writings of authors who enjoy a European reputation, and others who occupy a niche as innovators or recorders of social trends (Mann, Kafka, Fallada, Frank, Toller, Kaiser, Brecht, and others). Conducted in German. (*Not offered 1961–62.*) *Bon*

23.17 *Scientific German*
Prereq.: ——
Year: G (1) 3–0–6
Intensive preparation for graduate language requirement in German. No previous study of German required. Group meetings for discussion of ways to facilitate comprehension of grammatical and syntactical difficulties. Section meetings by Courses for reading material in the field of the student. (*Open to graduate students only. No credit given.*) *Bon*

23.20 *Great Books and Authors in German Literature*
Prereq.: 23.14T
Year: U (2) 3–0–5
Reading and discussion of outstanding works in the drama, poetry and prose fiction of German literature. Period 1750–1830. Goethe, Schiller, Grillparzer, and Kleist. Selections from the poetry of Goethe and Schiller. Selections from the prose of Goethe and Kleist. Conducted in German. *Bon*

23.21T *Contemporary German Literature*
Prereq.: 23.14T
Year: U (1) 3–0–5
A survey of German literature after 1945. The impact of military defeat on literature. The problems of the post-war generation. Selected writings in prose, poetry, and drama. Conducted in German. *Kirshner*

23.22 *Spoken German*
Prereq.: 23.13 or 3 years high school German
Year: U (2) 3–0–5
For students with little or no experience in using the spoken language. Recently developed techniques used to convert reading knowledge into ability to comprehend the spoken language. Full use made of mechanical devices for improving intonation and pronunciation. Emphasis on development of basic vocabulary of words and phrases used in everyday conversation. Appropriate for Fulbright candidates. *Bon*

23.51 *Elementary French*
Prereq.: ——
Year: U (1) 3–0–5

23.52 *Elementary French*
Prereq.: 23.51
Year: U (2) 3–0–5
Necessary foundation for French language and literature, or for scientific studies. Training in pronunciation, elementary grammar, acquisition of useful vocabulary; reading of varied matter, part of which deals with French institutions and the history of France; practice in hearing and speaking French. *Gendzier*

23.53 *Intermediate French*
Prereq.: 23.52 or 2 years high school French
Year: U (1) 3–0–5
Practice in spoken French to develop fluency in everyday conversation; also in written French to increase accuracy. Mechanical devices used for improving pronunciation and intonation. Appropriate for Fulbright candidates. *Bottiglia*

23.54T *Conversational French*
Prereq.: 23.53 or 3 years of high school French
Year: U (2) 3–0–5
Practice in spoken French to develop fluency in cultural conversation; also in written French to increase accuracy. Appropriate for Fulbright candidates. *Bottiglia*

23.56 *French Literature of the Third Republic*
Prereq.: 23.54T
Year: U (2) 3–0–5
Study of literary works from 1870 to 1940. Stress on the major figures. Conducted in French. (*Not offered 1961–62.*) *Gendzier*

23.57 *Scientific French*
Prereq.: ——
Year: G (2) 3–0–6
Intensive preparation for graduate language requirement in French. No previous study of French required. Group meetings for discussion of ways to facilitate comprehension of grammatical and syntactical difficulties. Section meetings by Courses for reading material in the field of the student. (*Open to graduate students only. No credit given.*) *Bon*

23.59T *French Literature: Classicism and the Enlightenment*
Prereq.: 23.54T
Year: U (1) 3–0–5
Study of seventeenth and eighteenth century literature. Stress on the major figures. Conducted in French. (*Not offered 1961–62.*) *Gendzier*

23.61T *French Literature: Romanticism and Realism*
Prereq.: 23.54T
Year: U (1) 3–0–5
Study of nineteenth century Romantic and Realistic literature. Stress on the major figures. Conducted in French. *Gendzier*

23.62T *Contemporary French Literature*
Prereq.: 23.54T
Year: U (2) 3–0–5
Study of literary works from 1940 to the present. Stress on the major figures. Conducted in French. *Gendzier*

23.701 *Crucial Problems in Linguistics*
Prereq.: ——
Year: G (1) *Arr.*
Word: form and meaning, grammatical and lexical analysis. Word classes and morphological categories. Grammatical and lexical structure of society. *Jakobson*

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23.71 ***Special Problems in Language and Literature***
Prereq.: ——
Year: G (1) *Arr.*

23.72 ***Special Problems in Language and Literature***
Prereq.: ——
Year: G (2) *Arr.*
Advanced work in literature or linguistics for unusually well-prepared students. Offered by members of staff in their special fields. *Staff*

23.731 ***Structure of English*** **(A)**
Prereq.: 23.751
Year: G (1) 3–0–9
Syntax: detailed study of the grammatical structure of sentences in contemporary English. Special reference to formal correlates of traditional grammatical statements about English syntax, such as those by Jespersen, Poutsma, and Curme. Consideration of current descriptions of English syntax, such as those by Harris, Hill, and Fries. *Klima*

23.732 ***Structure of English*** **(A)**
Prereq.: 23.731
Year: G (2) 3–0–9
Morphology and phonology: Continuation of 23.731. The interrelation of syntactic morphological and phonological phenomena in the English language. The phonological system and the structure of morphemes. Special reference to current interpretations by leading structuralists. The dialectology and historical phonology of English. *Klima*

23.751 ***Language and Society***
Prereq.: ——
Year: G (1) 3–0–5
Introduction to the scientific study of human language. Outline of syntactic theory; brief survey of English syntax. Elementary data on production and physical nature of speech. The phoneme and distinctive features. Phonemic systems. Morphology: review of some morphological devices. Languages of the world, their historical relationships and structural classification. Speech and writing. Language, culture and cognition. *Halle*

23.761 ***Problems of Phonology***
Prereq.: 23.751
Year: G (2) 3–0–3
Aims and principles of a scientific description of the structure of a spoken language. The mechanism and the acoustics of speech. The phonemic system of a language. The pair test. Distinctive features as a descriptive framework. The phoneme. The interrelation between phonology and other linguistic levels. Some problems of historical phonology. Practical exercises in preparing a phonemic analysis of a language with the help of a native informant. *Halle*

23.781 ***Survey of General Linguistics*** **(A)**
Prereq.: 23.751
Year: G (1) 3–0–9
Critical study of a series of major works on the nature of language. Readings in linguistics, philosophy, and psychology. *Chomsky*

23.782 ***Linguistic Structure***
Prereq.: ——
Year: G (2) 3–0–9
Problems and methods of the descriptive study of language. *Study of form in language:* definition and determination of linguistic elements; mathematical models for linguistic behavior; construction of an objective and abstract theory of formal linguistic structure; systematic application of this theory to the description of English structure. *Study of meaning in language:* relation of linguistic form and meaning; various approaches to a theory of meaning; contemporary philosophy of language and the influence of symbolic logic; extensional and intensional structure. Comparison of the logic of natural languages with that of special purpose language systems (i.e., mathematics, science). *Chomsky*

23.791 ***Language, Symbolic Processes, and Computers***
Prereq.: 6.25 or 8.07 or 18.08 or 23.751
Year: G (1) 3–0–9
Symbols, their storage and manipulation: formal systems of symbols, natural languages, computer programming languages, codes, notation systems of mathematics, logic, physics, etc.; relation of symbols and symbol systems to the physical means of representation and manipulation; relation of symbols and symbol systems to the subject matter represented and its systematization; symbolic processes, induction, deduction, reasoning; translation and translatability. *Yngve*

23.792 ***Mechanical Translation and Language Processing***
Prereq.: 23.791
Year: G (2) 3–0–9
A survey of research in the area of language processing by machine. Successes and inadequacies of current techniques. Remaining obstacles to adequate mechanical translation. Morphology; syntax; lexicography; semantics; automatic analysis and synthesis of sentences. Structure of English, German and other languages. *Yngve*

23.87 ***Dante I***
Prereq.: ——
Year: U (1) 3–0–5
Intensive literary analysis of the *Inferno* in the original, after preliminary training in fundamentals of Italian grammar and pronunciation. Designed for students with no previous knowledge of Italian. *Bottiglia*

23.88 ***Dante II***
Prereq.: 23.87
Year: U (2) 3–0–5
Continuation of 23.87. Intensive literary analysis of the *Purgatorio* and the *Paradiso* in the original. *Bottiglia*

23.91 ***Elementary Russian***
Prereq.: ——
Year: U (1) 3–0–5

23.92 ***Elementary Russian***
Prereq.: 23.91
Year: U (2) 3–0–5
Essentials of grammar, practice in hearing, pronunciation, speaking and translation of connected stories. *Lipson*

23.93 ***Intermediate Russian***
Prereq.: 23.92
Year: U (1) 3–0–5

23.94 ***Intermediate Russian***
Prereq.: 23.93
Year: U (2) 3–0–5
Continuation of pronunciation and practice in conversation; reading of material on Russia, some standard modern authors. *Caffrey*

23.95 ***Great Books and Authors in Russian Literature***
Prereq.: 23.94
Year: U (1) 3–0–5
Reading and discussion of the outstanding works in the drama, poetry, and prose fiction of Russian literature. Conducted in Russian. *Mlikotin*

23.96 ***Modern Russian Literature***
Prereq.: 23.94
Year: U (2) 3–0–5
Reading and study of modern literary works for the light which they throw on Russian thought and action leading up to and since the Revolution. Conducted in Russian. (*Not offered 1961–62.*) *Mlikotin*

23.97 ***Scientific Russian***
Prereq.: ——
Year: G (2) 3–0–6
Intensive preparation for graduate language requirement in Russian. No previous study of Russian required. Group meetings for discussion of ways to facilitate comprehension of grammatical and syntactical difficulties. Section meetings by Courses for reading material in the field of the student. (*Open to graduate students only. No credit given.*) *Browne*

23.98 ***Soviet Literature and the West***
Prereq.: 23.94
Year: U (2) 3–0–5
Study of the works of Soviet and Western writers for the impact of Communist ideology and practice on the traditional values in thought, ethics, and art. Readings in translation or in the original from authors such as Gorky, Block, Mayakovsky, Sholohov, Ehrenburg, Gide, Silone, Sartre, Wright, Koestler, Pasternak, and Miklosz. Conducted in Russian. *Mlikotin*

(See also 21.69T, SYMBOLIC LOGIC; 14.77, PSYCHOLOGY OF LANGUAGE AND COMMUNICATION; and 6.574, TRANSMISSION OF INFORMATION.)

AS
Air Science

AS11 ***Evolution of Warfare***
Prereq.: ——
Year: 1 (1) 3–1–5
Study of the historical development of the principles of war and military policy based on technological advances, and study of the political, economic, psycho-social, and military factors of national power. Investigation of the evolution of the United States Department of Defense and the definitive approach to current concepts of warfare and national strategy. Officer leadership training during laboratory periods. (*Restricted to students selected for A.F.R.O.T.C.*) *Brachtenbach*

AS12 ***Foundations of Air Power***
Prereq.: AS11
Year: 1 (2) 3–1–5
Study of the historical development of air power, with emphasis on its employment in the past, present and future, as influenced by technological developments and their effects on military concepts and world political situations. Officer leadership training during laboratory periods. (*Restricted to students selected for A.F.R.O.T.C.*) *Sena*

AS21T ***U.S. Air Force Weapon Systems***
Prereq.: AS12
Year: U (1) 0–1–0

AS22T ***Aerospace Research Vehicles and Systems***
Prereq.: AS21T
Year: U (2) 0–1–0
Lecture series on technological aspects and current concepts of U. S. Air Force aircraft, missiles, satellites and other research systems. Further training in the art of leadership. (*Restricted to students selected for A.F.R.O.T.C.*) *R. C. Shoemaker*

AS31 ***Research and Development in the U.S. Air Force***
Prereq.: AS22T
Year: U (1) 0–1–0

AS32 ***Preparation for Command and Staff Positions***
Prereq.: AS31
Year: U (2) 0–1–0
Lecture series on organization and administration for research and development in the Air Force with emphasis on current research activities. Introduction to principles and psychology of leadership. (*Restricted to students selected for A.F.R.O.T.C.*) *R. C. Shoemaker*

AS41T ***Principles and Techniques of Leadership***
Prereq.: AS32
Year: U (1) 3–1–5
Thorough investigation of the communicative process both oral and written, with special emphasis on improving each student's ability to express himself and to impart information or directions. Methods of instruction and teaching techniques. Understanding of people and interpersonal relations. (*Restricted to students selected for A.F.R.O.T.C.*) *J. D. Alexander*

AS42T ***Global Geography***
Prereq.: AS41T
Year: U (2) 3–1–5
Development of the understanding of geographic fundamentals and concepts to allow the student to evaluate the political behavior of states, or aggregates of states, insofar as behavior is affected by geography, and to develop an understanding of the relationship between global strategic views and geography. Information concerning the Air Force that will be needed by the student on his entry to active duty. (*Restricted to students selected for A.F.R.O.T.C.*) *J. D. Alexander*

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MS
Military Science

MS11 ***Military Science***
Prereq.: ——
Year: 1 (1) 2–1–0
MS12 ***Military Science***
Prereq.: MS11
Year: 1 (2) 2–1–0
Organization of the Department of Defense; individual weapons; the United States Army and national security; school of the soldier and exercise of command; military history; chemical, biological, and radiological warfare. *Staff*

MS21 ***Military Science***
Prereq.: MS12
Year: U (1) 2–1–0
MS22 ***Military Science***
Prereq.: MS21
Year: U (2) 2–1–0
Military teaching methods; map reading and aerial photograph reading; basic tactics; school of the soldier and exercise of command; U. S. Army and national security; chemical, biological and radiological warfare. *Staff*

MS312 ***Advanced Corps of Engineers***
Prereq.: MS22
Year: U (1) 3–0–1
MS322 ***Advanced Corps of Engineers***
Prereq.: MS312
Year: U (2) 2–1–1
Leadership; school of the soldier and exercise of command; branch material instruction in the following specialized areas: military explosives; mine warfare; fortifications and camouflage construction; construction materials; military structures; engineer computations and layout; concrete and bituminous construction. *Scheider*

MS313 ***Advanced Signal Corps***
Prereq.: MS22
Year: U (1) 3–0–1
MS323 ***Advanced Signal Corps***
Prereq.: MS313
Year: U (2) 2–1–1
Leadership; school of the soldier and exercise of command; branch material instruction in the following specialized areas: signal field communications system engineering; signal command and staff; military intelligence. *J. M. Norton*

MS314 ***Advanced Ordnance Corps***
Prereq.: MS22
Year: U (1) 3–0–1
MS324 ***Advanced Ordnance Corps***
Prereq.: MS314
Year: U (2) 2–1–1
Leadership; school of the soldier and exercise of command; branch material instruction in the following specialized areas; role of the Ordnance Corps; ammunition, armament, automotive, and guided missile technology. *Ireland*

MS316 ***Advanced Chemical Corps***
Prereq.: MS22
Year: U (1) 3–0–1
MS326 ***Advanced Chemical Corps***
Prereq.: MS316
Year: U (2) 2–1–1
Leadership; school of the soldier and exercise of command; branch material instruction in the following specialized areas: development and mission of the Chemical Corps; characteristics and employment of chemicals, biologicals, introduction to radiological warfare. *Shadle*

MS318 ***Advanced Quartermaster Corps***
Prereq.: MS22
Year: U (1) 3–0–1
MS328 ***Advanced Quartermaster Corps***
Prereq.: MS318
Year: U (2) 2–1–1
Leadership; school of the soldier and exercise of command; branch material instruction in the following specialized areas: principles of supply; procurement; aerial supply and delivery; quartermaster operations in the theater of operations. *A. E. Andrews*

MS412 ***Advanced Corps of Engineers***
Prereq.: MS322
Year: U (1) 3–0–1
MS422 ***Advanced Corps of Engineers***
Prereq.: MS412
Year: U (2) 2–1–1
School of the soldier and exercise of command; military administration; military justice; role of the United States in world affairs; logistics; operations; officer indoctrination; branch material instruction in the following specialized areas: engineer logistical activities; employment of engineer units; staff procedures; construction management; military roads and airfields; buildings and utilities. *Scheider*

MS413 ***Advanced Signal Corps***
Prereq.: MS323
Year: U (1) 3–0–1
MS423 ***Advanced Signal Corps***
Prereq.: MS413
Year: U (2) 2–1–1
School of the soldier and exercise of command; military administration; military justice; role of the United States in world affairs; logistics; operations; officer indoctrination; branch material instruction in the following specialized areas; higher echelon signal systems; automatic data processing in the Army; Signal Corps pictorial and television activities. *J. M. Norton*

MS414 ***Advanced Ordnance Corps***
Prereq.: MS324
Year: U (1) 2–1–1
MS424 ***Advanced Ordnance Corps***
Prereq.: MS414
Year: U (2) 3–0–1
School of the soldier and exercise of command; military administration; military justice; role of the United States in world affairs; logistics; operations; officer indoctrination; branch material instruction in the following specialized areas; ordnance management; tools of ordnance management. *Ireland*

MS416 ***Advanced Chemical Corps***
Prereq.: MS326
Year: U (1) 2–1–1
MS426 ***Advanced Chemical Corps***
Prereq.: MS416
Year: U (2) 3–0–1
School of the soldier and exercise of command; military administration; military justice; role of the United States in world affairs; logistics; operations; officer indoctrination; branch material instruction in the following specialized areas: nuclear warfare and nuclear defense; chemical combat and technical intelligence. *Shadle*

MS418 ***Advanced Quartermaster Corps***
Prereq.: MS328
Year: U (1) 3–0–1
MS428 ***Advanced Quartermaster Corps***
Prereq.: MS418
Year: U (2) 2–1–1
School of the soldier and exercise of command; military administration; military justice; role of the United States in world affairs; logistics; operations; officer indoctrination; branch material instruction in the following specialized areas: logistical organization in the continental U.S.; quartermaster activities at installations; petroleum supply functions; food program. *A. E. Andrews*

NS
Naval Science

NS11 ***Orientation and Sea Power***
Prereq.: ——
Year: 1 (1) 3–1–5
NS12 ***Orientation and Sea Power***
Prereq.: NS11
Year: 1 (2) 3–1–5
Fundamentals of naval knowledge. Concepts of use of sea power from geographical, geopolitical and national strategical considerations. Influence of sea power in shaping world affairs socially, politically and economically. (*Restricted to students selected for N.R.O.T.C.*) *Curry*

NS21 ***Naval Guided Missiles***
Prereq.: NS12
Year: U (1) 1–0–0
NS22 ***Naval Guided Missiles***
Prereq.: NS21
Year: U (2) 1–0–0
Lecture series on technological fundamentals of present day naval guided missiles. (*Restricted to students selected for N.R.O.T.C.*) *Chichester*

NS31 ***Naval Nuclear Propulsion***
Prereq.: NS22
Year: U (1) 1–0–0
NS32 ***Naval Nuclear Propulsion***
Prereq.: NS31
Year: U (2) 1–0–0
Lecture series on technological fundamentals of applied and planned naval nuclear propulsion plants. (*Restricted to students selected for N.R.O.T.C.*) *Baylis*

NS41 ***Naval Industrial Management and Leadership***
Prereq.: NS32
Year: U (1) 3–1–5
NS42 ***Naval Industrial Management and Leadership***
Prereq.: NS41
Year: U (2) 3–1–5
Study of the principles and applications of industrial management and leadership subjects as applied to naval situations; naval industrial management; social psychology as applied to leadership and naval leadership. (*Restricted to students selected for N.R.O.T.C.*) *Chichester*

SEM
Undergraduate Seminar

SEM11 ***Undergraduate Seminar***
Prereq.: ——
Year: 1 (1) 0–6–0
SEM12 ***Undergraduate Seminar***
Prereq.: ——
Year: 1 (2) 0–6–0
Seminar and/or research work for freshmen in a small group under leadership of a staff member. A description of seminars and research projects offered is published each term. Application for all seminars is made to the Undergraduate Seminar Office. Enrollment may be limited; selection of participants is made by the staff member offering the seminar. *Gilliland*

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THE DEPARTMENTAL VISITING COMMITTEES[1]

as of August 1, 1961

AERONAUTICS AND ASTRONAUTICS

WILLIAM ARMISTEAD MOALE BURDEN
William A. M. Burden and Company

LEONARD SINCLAIR HOBBS
Director,
United Aircraft Corporation

WILLIAM LITTLEWOOD
Vice President for Equipment Research,
American Airlines, Inc.

CHARLES J. McCARTHY
Former Chairman,
Chance Vought Aircraft, Inc.

FRANK PACE, JR.
Chairman,
General Dynamics Corporation

SELDEN B. SPANGLER
Vice Admiral, U.S.N. (Ret.);
Director of Research,
Garrett Corporation

LAURENCE LAVERNE WAITE
Senior Vice President,
Engineering and Planning,
North American Aviation, Inc.

ARCHITECTURE

BISSELL ALDERMAN
Alderman and MacNeish, Architects

ALDEN BALL DOW
Architect, Midland, Michigan

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ROBERT EARLE DURLAND
Buyer

BUSINESS ADMINISTRATION

PHILIP ARNOLD STODDARD, S.B.
Vice President, Operations and Personnel

Operations

CARL MAGNUS FRITHIOF PETERSON, S.M.
Director of the Physical Plant

DONALD WHISTON, S.B.
General Superintendent

JEROME HAZELTON BARRAFORD, B.S.
Superintendent of Power and Utilities

MILES PAYNE COWEN
Superintendent of Building Services

EDWARD THOMAS PIEPER, B.A., S.B.
Construction Manager

HORACE STANLEY PALMER, S.B.
Assistant Superintendent of Power and Utilities

THEODORE JORDAN
Assistant to the Director of the Physical Plant

WILLIAM ROBERT DICKSON, S.B.
Assistant to the Director of the Physical Plant

RAYMOND SEYMOUR HOWELL
Building Maintenance Assistant

JAMES FRANCIS BRADY
Assistant to the General Superintendent

MARK JOHN DONDERO, B.S.
Safety Engineer

JOHN MICHAEL FRESINA, B.A.
Assistant to the Safety Engineer

HENRY KENNETH DOW, A.B.
Manager of the Dormitories

FRANK HERBERT CONANT
Manager of the Photographic Service

DANIEL GRAHAM WEBSTER
Assistant Manager of the Photographic Service

OVADIA ROBERT SIMHA, M.C.P.
Planning Officer

JAY LEWIS MARDEN, B.S.
Assistant to the Vice President, Operations and Personnel

Personnel Relations

ROBERT JONES DAVIS, B.S.
Director of the Office of Personnel Relations

ALBERT FLEETFORD SISE
Associate Director of the Office of Personnel Relations

HAROLD EMIL DREYER, PH.D.
Supervisor of Employee Benefits

JOSEPH FRANCIS O'CONNOR, A.B.
Personnel Officer for Professional Personnel

IDELLA LYMAN TAPLEY, A.B.
Personnel Officer for Office Personnel

JAMES JOSEPH FANDEL, B.A., M.S.
Personnel Officer for Hourly Personnel

JOHN ALEXANDER CARLEY, A.B.
Supervisor of Training and Information

JOHN PAUL KARLE, B.S., M.A.
Assistant to the Personnel Officer

HENRY JOSEPH LEONARD
Assistant to the Personnel Officer

JOSEPH ANDREW McDONOUGH, B.A., J.D.
Assistant to the Personnel Officer

WILLIAM HAMILTON CARLISLE, JR.
Manager of Student Personnel

NORMAN STEPHEN SIDNEY
Captain, Campus Patrol

Other Administrative Departments and Offices

RESIDENT STAFF OF THE ALUMNI ASSOCIATION

HAROLD EDWARD LOBDELL
Executive Vice President

DONALD PORTER SEVERANCE, S.M.
Secretary and Treasurer

FREDERICK GLIESSMANN LEHMANN, S.B.
Assistant Secretary

MADELINE RUTH McCORMICK
Assistant Treasurer

VOLTA WRAY TORREY, A.B.
Editor of "The Technology Review"

RALPH THEODORE JOPE, S.B.
Business Manager of "The Technology Review"

HENRY BUGBEE KANE, S.B.
Director of the Alumni Fund

DOUGLAS FENNO GOSS HAVEN, S.B.
Director for Regions

DEVELOPMENT OFFICE

JOHN WESLEY SHEETZ, III, S.M.
Director

WALTER HENRY GALE, S.M.
Special Assistant

JAMES GERALD KELSO, PH.D.
Special Assistant

DOW HUGH DARDEN, LL.B., A.M.
Special Assistant

JOSEPH JAMES LAMBERT, B.S.
Assistant to the Director

SCOTT DAVID LOTHROP, A.B., M.S.
Assistant to the Secretary of the Institute

LOWELL INSTITUTE SCHOOL

FRANKLIN LEROY FOSTER, SC.D.
Director

M.I.T. PRESS

LYNWOOD SILVESTER BRYANT, A.M.
Director

HAROLD FINE CHEVALIER, A.B.
Production Manager

PUBLIC RELATIONS

FRANCIS ERNEST WYLIE, A.B.
Director of Public Relations

JOHN ISHAM MATTILL, M.A.
Director of Publications; Associate Director of Public Relations

GEORGE DENMAN WOOD, JR., B.A., M.S.
Assistant Director of Public Relations

WILLIAM THORNTON STRUBLE, A.B.
Assistant Director of Public Relations

NELSON COOPER LEES, S.B., M.A.
Assistant to the Director of Public Relations

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DOROTHY ANNE BLAIR, A.B.
CONSTANCE DORAINE BOYD, A.M.
CAROLYN BRADBURY COX
CLAIRE PERHAM EDWARDSON
BESSIE HOWLAND GROGGETT, A.B.
MARGARET CLARK HOPKINS
MARY CATHERINE HURLEY
KENNETH KING, JR., S.M.
PATRICIA MAY MacDONALD, B.A.
JULIA CATHERINE McLELLAN
LORETTA HELEN MANNIX, B.S., M.A.
PRISCILLA ESTELLE MEAD, B.A.
ELSA NABER, A.B.
ELIZABETH AILEEN PIGOTT
STANLEY NORMAN ROACH, B.B.A.

ADMINISTRATIVE OFFICERS, EMERITI

GEORGE W. MORSE, M.D.
Professor, Emeritus; Medical Director, Emeritus

ROBERT GRANVILLE CALDWELL, PH.D., D.LITT.
Dean of Humanities, Emeritus

HORACE SAYFORD FORD, LL.D.
Treasurer, Emeritus

JOHN WYMOND MILLER BUNKER, PH.D., SC.D.
Dean of the Graduate School, Emeritus

JOSEPH CHRISMAN MACKINNON, S.B.
Registrar, Emeritus

DELBERT LEON RHIND
Assistant Treasurer, Emeritus

JOHN JAMES ROWLANDS
Director of the News Service, Emeritus

HELEN ELIZABETH MACKINNON
Assistant to the Registrar, Emerita

BRAINERD ALDEN THRESHER, S.B., A.M
Professor Emeritus; Director of Admissions, Emeritus

Libraries

MARGUERITE CHAMBERLAIN, A.B., S.B.
Emerita

MARGARET MORRIS DE LEVIN, S.B., M.A.
Emerita

RUTH McGLASHAN LANE, B.A., S.B., ED.M.
Emerita

MIRIAN SPRAGUE SMITH, S.B.
Emerita

BERTHA PRESTON TRULL, A.B.
Emerita

OFFICERS AND COMMITTEES OF THE FACULTY

JULIUS ADAMS STRATTON, SC.D., D.ENG., LL.D.
President

PATRICK MASON HURLEY, PH.D.
Chairman of the Faculty

CHARLES HARD TOWNES, PH.D., D.LITT.
Provost

PHILIP FRANKLIN, PH.D.
Secretary of the Faculty

WILLIAM CHACE GREENE, M.A.
Assistant Secretary of the Faculty

MEMBERS OF THE FACULTY EX OFFICIIS

JAMES R. KILLIAN, JR.
Chairman of the Corporation

JAMES McCORMACK
Vice President

CARL F. FLOE
Vice President, Research Administration

MALCOLM G. KISPERT
Vice President, Academic Administration

ARTHUR L. SINGER, JR.
Assistant Dean of the School of Humanities and Social Science

ALBERT O. SEELER
Medical Director

FREDERICK G. FASSETT, JR.
Dean of Residence

ROBERT E. HEWES
Registrar

ROSS H. SMITH
Director of Athletics

THOMAS P. PITRÉ
Associate Dean of Students

WILLIAM SPEER
Associate Dean for Student Counseling

ROBERT J. HOLDEN
Associate Dean of Students

PAUL M. CHALMERS
Associate Director of Admissions

EUGENE R. CHAMBERLAIN
Associate Director of Admissions

M. BRYCE LEGGETT
Associate Director of Admissions

WARREN D. WELLS
Associate Registrar

JAMES H. EACKER
Assistant Director of Admissions

ROBERT K. WEATHERALL
Assistant Director of Admissions

FACULTY COMMITTEES, 1961–62[1]

Academic Performance ‡

SECRETARY * (*Chairman*)
DEAN OF STUDENT AFFAIRS *
REGISTRAR *
DIRECTOR OF THE MEDICAL DEPARTMENT *
DIRECTOR OF STUDENT AID *

ELIE J. BAGHDADY	1962
CLIFFORD G. SHULL	1962
JOSEPH BICKNELL	1963
GEORGE P. WADSWORTH	1963
S. WILLIAM GOUSE, JR.	1964
CHARLES KINGSLEY, JR.	1964

Admissions ‡

DONALD R. F. HARLEMAN (*Chairman*) 1962
DIRECTOR OF ADMISSIONS *
DIRECTOR OF STUDENT AID *
REGISTRAR *

FRANCIS M. BATOR	1962
HARALD A. ENGE	1963
J. FRANCIS REINTJES	1963
DAVID DURAND	1964
JOHN R. MYER	1964

Curricula ‡

WALTER WRIGLEY (*Chairman*) 1963
REGISTRAR *
CHAIRMAN OF THE FRESHMAN ADVISORY COUNCIL *

NORMAN N. HOLLAND	1962
FELIX M. H. VILLARS	1962
FRANCIS B. HILDEBRAND	1963
DEAN N. ARDEN	1964
ROGER W. BROWN	1964

Discipline ‡

HOULDER HUDGINS (*Chairman*) 1962
DEAN OF STUDENT AFFAIRS *

ROBLEY D. EVANS	1962
RICHARD L. BALCH	1963
DOUGLAS M. McGREGOR	1963
KLAUS LIEPMANN	1964
ROBERT B. NEWMAN	1964

Educational Policy

PATRICK M. HURLEY (*Chairman*)
(other members to be announced)

Graduate School Policy

DEAN OF THE GRADUATE SCHOOL * (*Chairman*)
SECRETARY OF THE GRADUATE SCHOOL * (*Secretary*)
DIRECTOR OF ADMISSIONS *
CHAIRMAN OF THE FACULTY *
MARTIN A. ABKOWITZ
JAMES M. AUSTIN
E. CARY BROWN
EDUARDO F. CATALANO
HAROLD W. FAIRBAIRN
TRUMAN S. GRAY
MORRIS HALLE
MYLE J. HOLLEY, JR.
DAVID N. HUME
GEORGE F. KOSTER
KEVIN A. LYNCH
HENRY P. McKEAN, JR.
DONALD G. MARQUIS
JOHN T. R. NICKERSON
JOHN T. NORTON
NORMAN J. PADELFORD †
WARREN M. ROHSENOW
DAVID J. ROSE
LEON TRILLING
DAVID F. WAUGH
GLENN C. WILLIAMS

Industrial Liaison

BRANDON G. RIGHTMIRE (*Chairman*) 1962

ALAN S. MICHAELS	1962
EDWARD H. BOWMAN	1963
FREDERICK J. McGARRY	1963
ALBERT G. H. DIETZ	1964
ROBERT K. MUELLER	1964

Libraries

Executive Board:

HAROLD W. FAIRBAIRN (*Chairman*) 1962
DIRECTOR OF LIBRARIES *
ASSOCIATE DIRECTOR OF LIBRARIES *

JOHN F. ELLIOTT †	1963
KURT S. LION	1963
EVSEY D. DOMAR	1964
STANLEY BACKER †	1965
KEVIN A. LYNCH	1965

Advisory Board:

RAYMOND F. BADDOUR
JOSEPH BICKNELL
WILLIAM F. BOTTIGLIA
DOUGLASS V. BROWN
JERRY B. CHICHESTER
CECIL G. DUNN
SIGURDUR HELGASON
NORMAN N. HOLLAND
IRVING KAPLAN
JUSTIN E. KERWIN
CHARLES KINGSLEY, JR.
GEORGE F. KOSTER
HENRY A. MILLON
EUGENE MIRABELLI
NORMAN A. PHILLIPS
DAVID A. SENA
CHARLES M. SHADLE
C. GARDNER SWAIN

Nominations

HAROLD S. MICKLEY (*Chairman*)
T. WILLIAM LAMBE
ROY LAMSON
CHIA-CHIAO LIN
NORMAN J. PADELFORD
CLARK C. STEPHENSON

Staff — Administration

Staff:

JOHN W. IRVINE, JR. (*Chairman*) 1963

SANBORN C. BROWN	1962
MARVIN E. GOODY	1962
JAMES B. STONE	1963
JOHN G. KING	1964
THOMAS K. SHERWOOD	1964

Administration:

GORDON S. BROWN
GEORGE R. HARRISON
MALCOLM G. KISPERT
JAMES McCORMACK
JOSEPH J. SNYDER
JULIUS A. STRATTON
CHARLES H. TOWNES

Student Aid ‡

MARTIN WOHL (*Chairman*) 1962
DIRECTOR OF STUDENT AID *

FREDERICK J. ADAMS	1962
JOHN S. WAUGH	1963
DAVID R. WHITEHOUSE	1963
GEORGE W. CLARK	1964
JOHN W. WINCHESTER	1964

Student Environment ‡

HOLT ASHLEY (*Chairman*) 1963
DEAN OF STUDENT AFFAIRS *
DEAN OF RESIDENCE *

KEVIN A. LYNCH	1962
ALBERT O. SEELER	1962
ROBERT J. HANSEN	1963
ARTHUR L. LOEB	1964
F. ALBERT COTTON	1964

COMMITTEE ON THE JOINT CENTER FOR URBAN STUDIES 1961–62[2]

Administration

CARL F. FLOE (*Chairman*)
PIETRO BELLUSCHI
JOHN E. BURCHARD
DON K. PRICE, JR., *Harvard*
NATHAN M. PUSEY, *Harvard*
JOSE L. SERT, *Harvard*

Faculty

LLOYD RODWIN (*Chairman*)
SIDNEY S. ALEXANDER
JOHN M. GAUS, *Harvard*
CHARLES M. HAAR, *Harvard*
JOHN T. HOWARD
REGINALD R. ISAACS, *Harvard*
MARTIN MEYERSON, *Harvard*
CHARLES L. MILLER
MAX F. MILLIKAN
JOHN C. SNYDER, *Harvard*
SAMUEL A. STOUFFER, *Harvard*

COMMITTEES ON JOINT PROJECTS, 1961–62

Plastics

ALBERT G. H. DIETZ (*Chairman*)
FRANK A. McCLINTOCK
FREDERICK J. McGARRY
ALAN S. MICHAELS
EGON OROWAN
EDWARD R. SCHWARZ

Steering Committee on Solar Energy Research

GEORGE R. HARRISON (*Chairman*)
LAWRENCE B. ANDERSON
GORDON S. BROWN
ARTHUR C. COPE
NATHANIEL H. FRANK
THOMAS K. SHERWOOD

* *Ex officio* † Appointed by the President
‡ A member of the Committee on Educational Policy to be appointed to serve *ex officio*.
[1] The dates to the right indicate the years in which the terms of appointment expire.
[2] A joint project of Harvard University and M. I. T.

COMMITTEES ON INTERDEPARTMENTAL LABORATORIES, 1961–62

Electronics

HENRY J. ZIMMERMANN (*Chairman*)
WILLIAM W. BUECHNER
WILBUR B. DAVENPORT, JR.
PETER ELIAS
GEORGE G. HARVEY
ALBERT G. HILL

Nuclear Science

MARTIN DEUTSCH (*Chairman*)
DEAN OF THE SCHOOL OF SCIENCE *
MANSON BENEDICT
ARTHUR C. COPE
NATHANIEL H. FRANK
JERROLD R. ZACHARIAS

Directing Committee:
BERNARD T. FELD (*Chairman*)
WILLIAM W. BUECHNER
PETER T. DEMOS
MARTIN DEUTSCH
JERROLD R. ZACHARIAS

Spectroscopy

RICHARD C. LORD (*Chairman*)
FRANCIS BITTER
CARL W. GARLAND
GEORGE R. HARRISON

OTHER COMMITTEES AND BOARDS, 1961–62

Audit Committee of Student Activities

TRUMAN S. GRAY (*Chairman*)
ROBERT J. HOLDEN
EDWARD L. McCORMACK
GEORGE M. WYMAN (*Student*)

Commencement Committee

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CAROLYN B. COX (*Secretary*)
MILES P. COWEN
WILLIAM H. DENNEN
ROBERT E. HEWES
FREDERICK G. LEHMANN
ROBERT E. OGILVIE
CAMPBELL L. SEARLE

Faculty Committee on Inventions and Copyrights

CARL F. FLOE (*Chairman*)
ROBERT L. BISHOP
RAYMOND L. BISPLINGHOFF
JAY W. FORRESTER
GEORGE G. HARVEY
ALAN S. MICHAELS
JOHN C. SHEEHAN
DAVID C. WHITE

Hobby Shop Committee

JOHN W. SHEETZ, III (*Chairman*)
BENJAMIN L. AVERBACH
CARVEL COLLINS
ROBERT J. HOLDEN

Machine Methods of Computation and Numerical Analysis Committee

PHILIP M. MORSE (*Chairman*)
DEAN N. ARDEN
STEPHEN H. CRANDALL
DAVID DURAND
HERMAN FESHBACH
JAY W. FORRESTER
FRANCIS B. HILDEBRAND
CHARLES L. MILLER
MARVIN L. MINSKY
J. FRANCIS REINTJES
ROBERT M. SOLOW

M. I. T. Athletic Board

ROBERT E. MacMASTER (*Faculty*); (*Chairman*)
DEAN OF STUDENT AFFAIRS *
MEDICAL DIRECTOR *
O. ROBERT SIMHA (*Administration*) *
WALTER A. BACKOFEN (*Faculty*)
KENT F. HANSEN (*Faculty*)
ARTHUR L. BRYANT (*Alumnus*)
STUART EDGERLY, JR. (*Alumnus*)
I. CHENERY SALMON (*Alumnus*)
THOMAS G. BURNS (*Student*)
ROBERT A. LYTLE (*Student*)
CHESTER H. RILEY (*Student*)
PHILIP S. SCHMIDT (*Student*)

M.I.T. Press Board

JOHN E. BURCHARD (*Chairman*)
SIDNEY S. ALEXANDER
PETER ELIAS
FREDERICK G. FASSETT, JR.
CARL F. FLOE
FRANCIS L. FRIEDMAN
ERNEST M. HUNTRESS
MALCOLM G. KISPERT
ITHIEL D. POOL
LEON TRILLING

Operations Research Committee

PHILIP M. MORSE (*Chairman*)
DEAN N. ARDEN
EDWARD ARTHURS
EDWARD H. BOWMAN
DAVID DURAND
MARTIN GREENBERGER
RONALD A. HOWARD
CHARLES L. MILLER
HENRY M. PAYNTER
ROBERT M. SOLOW
GEORGE P. WADSWORTH

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MELVIN R. JENNEY
WILLIAM H. RADFORD
J. EDWARD VIVIAN

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SAMUEL LEVIN (*Secretary*)
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CYRUS LEVINTHAL
JOHN W. WINCHESTER

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DOUGLAS P. ADAMS
MARK J. DONDERO
HENRY W. FITZPATRICK
HARRIET L. HARDY
WOLCOTT A. HOKANSON
ROBERT L. LORIA
CARL M. F. PETERSON
NATHANIEL M. SAGE, JR.

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BENJAMIN L. AVERBACH
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JOHN W. IRVINE, JR.
JOHN C. SLATER
THEOS J. THOMPSON
PATRICK D. WALL

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HENRY W. BOWMAN (*Student*)
J. FRANK OSHA (*Student*)
GEORGE M. WYMAN (*Student*)

Student Financial Aid Board

THOMAS P. PITRÉ (*Chairman*)
J. SAMUEL JONES (*Secretary*)
CHAIRMAN OF THE COMMITTEE ON STUDENT AID * (MARTIN WOHL)
MARTIN GREENBERGER
WOLCOTT A. HOKANSON
JOHN T. HOWARD
MALCOLM G. KISPERT

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J. HARVEY EVANS
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EDWARD R. SCHWARZ

Ex officio

COUNCILS

ACADEMIC COUNCIL

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Vice President and Treasurer
Provost
Vice President
Vice President, Research Administration
Vice President, Academic Administration
Dean of the School of Engineering
Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Science
Dean of the School of Industrial Management
Dean of the Graduate School
Dean of Student Affairs
Chairman of the Faculty

ADMINISTRATIVE COUNCIL

President
Vice President and Treasurer
Provost
Vice President
Vice President, Research Administration
Vice President, Operations and Personnel
Vice President, Academic Administration
Dean of the School of Engineering
Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Science
Dean of the School of Industrial Management
Dean of the Graduate School
Dean of Student Affairs
Comptroller
Bursar
Chairman of the Faculty
Dean of Residence
Director of Admissions
Medical Director
Director of Athletics
Director of the Division of Sponsored Research
Director of the Industrial Liaison Office
Director of Libraries
Director of Lincoln Laboratory
Director of Public Relations
Director of Student Aid
Director of the Summer Session
Executive Vice President of the Alumni Association
Placement Officer
President of the Alumni Association
Registrar
Secretary of the Institute
Special Advisers to the President
Administrative Assistants to the President

FACULTY COUNCIL

Chairman of the Corporation
President
Provost
Vice President
Vice President, Research Administration
Vice President, Academic Administration
Dean of the School of Engineering
Dean of the School of Science
Dean of the School of Architecture and Planning
Dean of the School of Humanities and Social Science
Dean of the School of Industrial Management
Dean of the Graduate School
Dean of Student Affairs
Director of the Division of Sponsored Research
Chairman of the Faculty
Secretary of the Faculty
Director of the School for Advanced Study
Director of Libraries
Registrar
Director of Admissions
Director of the Research Laboratory of Electronics
Chairman of Directing Committee, Laboratory for Nuclear Science
Director of the Spectroscopy Laboratory
Director of the Lincoln Laboratory
Director of the Summer Session
Heads of Departments and Professional Courses
Chairman of the Committee on Educational Policy

Financial Aid for Undergraduates

A wide range of scholarship assistance is available to students entering from secondary schools; grants range from small awards up to and including amounts covering full tuition and living costs. In addition, M.I.T. loan funds are available in amounts less than full tuition during the freshman year — and thereafter in amounts up to full tuition for each year. The Student Financial Aid Committee will also make selections for on-the-campus part-time jobs to supplement requests for financial assistance.

All these forms of financial aid are in addition to the deferred payment plans described in Section 1 of this Catalogue.

Consideration for freshman financial aid grants is limited to students who are entering the Institute directly from secondary schools and who make application to the Director of Student Aid before January 15 of the calendar year in which they will enter. Selection for an award is based in general upon the Student Financial Aid Committee's evaluation of the candidate's total record; this includes College Entrance Examination Board test scores, high school or preparatory school records, evidence of need of financial assistance as determined from the Parents' Confidential Statement to the College Scholarship Service, and recommendations from his former teachers, prominent citizens of his community, or Institute alumni.

FRESHMAN SCHOLARSHIPS

The principal four-year scholarships -- the William Barton Rogers Scholarships, the Alumni Fund National Scholarships, the McDermott Scholarship, the Sloan National Scholarships, and others, including industrial grants — are open to all incoming candidates. Other scholarship grants depend, in part, upon a candidate's having some special qualification in addition to evidence of scholastic ability, such as that he come from a particular locality or be a graduate of a certain school. The Alumni Regional Scholarships, with awards for the freshman year, are limited to nineteen large metropolitan areas. A substantial number of Freshman Competitive Scholarships, with stipends varying from $300 to full tuition, are granted annually to qualified applicants who are not selected for a four-year award or an Alumni Regional Scholarship.

In the following list of freshman awards, the figure in parentheses gives the year when the scholarship or fund was established.

Sidney G. Albert Scholarship (1961)
This annual scholarship was established by Mr. Sidney G. Albert '29 for graduates of secondary schools who are residents of Long Island. Grants are for the freshman year only and are apportioned according to demonstrated need.

Alumni Regional Scholarships (1926)
As a means of cooperating with M.I.T. alumni in various centers in attracting to the Institute students of exceptional ability and promise, several Regional Scholarships, carrying an award based on demonstrated need for the freshman year, are offered in Chicago, Denver, Detroit, District of Columbia, Kansas City, Los Angeles, New York, New Jersey, Northern Ohio, Philadelphia, Pittsburgh, Portland, Ore., Rochester, N.Y., San Francisco, St. Louis, Seattle, Schenectady, Southern Ohio, and Westchester County, New York. These are open to American citizens of good character and health whose standing in their preparatory school studies has been high and who have satisfied with high standing all entrance requirements.

Army and Navy Scholarships (1930)
Sons of regular Army, Navy, Air Force, Marine Corps, and Coast Guard officers who are admitted as undergraduate students to the Institute will be considered for grants toward their tuition based on their demonstrated need, with a maximum of one-half tuition, upon recommendation of the Student Financial Aid Committee — the total number not to exceed ten each year. Preference will be given to qualified applicants admitted to the first-year class. Applications should be addressed to the Director of Student Aid and should be accompanied by documentary evidence that the applicant's father is a commissioned officer in the regular Army, Navy, Air Force, Marine Corps, or Coast Guard. Holders of these scholarships, if recommended by the Committee, may continue their grants during their second and succeeding undergraduate years.

John B. Bezazian Fund (1960)
This fund was established by the bequest of John B. Bezazian to furnish grants, including tuition and assistance toward living expenses, according to demonstrated financial need, for male students majoring in engineering or science. First preference is given in the selection to any qualified American male student of Armenian extraction residing in the United States of America; second preference to male students residing in the metropolitan or suburban area of Chicago, Illinois.

Bridgeport Scholarship (1932)
Established by the Institute through a bequest from Horace T. Smith '98, this is known as the Horace T. Smith Scholarship Fund. A scholarship, carrying a stipend based on demonstrated need with a maximum of full tuition for the freshman year, is annually offered to a graduate of the high schools of Bridgeport, Connecticut. Application should be made to the Director of Student Aid.

Cabot Foundation Scholarships (1955)
The income of a fund established by the Cabot Foundation, Inc., provides scholarships for children (sons *and* daughters) of employees of Godfrey L. Cabot, Inc., and its subsidiary and associated companies. Candidates are required to have certification of their eligibility for scholarship grants by first applying to the Personnel Office of Godfrey L. Cabot, Inc., and are expected to comply with the usual policies governing the award of Institute scholarships.

Cambridge Scholarships (1916)
A limited number of scholarships are granted to students entering the first-year class at the Institute who are graduates of schools in Cambridge and children of legal residents of that city. These Cambridge Scholarships, which carry a stipend of full tuition, are confined to students who make application furnishing evidence of need. An award may be continued in the second, third, and fourth years upon annual reapplication, providing the holder maintains a satisfactory scholastic record and continues to furnish evidence of need.

Class of 1895 Scholarship Memorial Fund (1945)
This fund was given by the Class of 1895 on its fiftieth anniversary, "the income annually to be used to provide scholarships for suitably qualified descendants of members of the Class of 1895. If in any year the total income is not required for this purpose, the balance shall be added to the Technology Loan Fund."

Class of 1922 Scholarship Fund (1942)
Established at the twentieth reunion of the Class of 1922, income and principal of this fund is used to "assist students entering the Institute as freshmen from secondary schools, with preference being given to sons (or daughters) of members of the Class." Beneficiaries "are expected to issue notes agreeing to repay the face value, without interest, of amounts received."

Class of 1931 Compton Memorial Freshman Scholarship Fund (1956)
The income from this fund, established at the twenty-fifth reunion of the Class of 1931 as a memorial to Dr. Karl Taylor Compton, is used for freshman scholarships.

Class of 1938 Scholarship Fund (1938)
Gifts from the Class of 1938, "the income for scholarships."

W. A. Conant Scholarship Fund (1943)
A bequest of $150,000 was made "for the purpose of establishing a permanent fund to be known as the W. A. Conant Scholarship Fund, the income therefrom to be used for the education of native born American Protestant boys of New England of American Protestant parents, who are graduates of some high or preparatory school, public or private, in New England, preference to be given to the graduates of the public schools of Brookline, Massachusetts, but without limitation thereto, and whose parents are financially unable to send them to the Institute and whose own means are insufficient to allow them to attend the Institute." One scholarship, carrying a grant of full tuition for each of the four undergraduate years, is annually offered to an entering freshman.

Ralph E. Curtis Scholarship (1960)
Income of this fund, established by gifts of the Curtis Universal Joint Company, Inc., is used to assist needy and worthy young men of Springfield, Massachusetts, to achieve their educational objectives at the Institute. Open to entering freshmen, initial preference is given to children and nephews and nieces of five-year employees of the Curtis Universal Joint Company, Inc. In the selection of awards for entering students, first preference is given to graduates of Springfield Technical High School; second preference to graduates of other Springfield high schools; and third preference to secondary school graduates resident in western Massachusetts.

Thomas C. Desmond Scholarship (1952)
Established by the gift of Thomas C. Desmond '09, a $1,500 scholarship for the freshman year is available to a student who plans to study civil engineering.

Development Fund Scholarships (1950)
Scholarships provided by gifts to the M.I.T. Development Fund consist of four-year grants to students who maintain academic ranking in the top quarter of the class and demonstrate continued need for financial assistance. A number of these awards are for full tuition, others for three-quarters tuition, and some for half tuition. They are open to all candidates from secondary schools. Application for renewal of these awards for each succeeding year should be made to the Student Financial Aid Committee.

William H. Donner Prize Scholarships (1956)
Six prize scholarships donated by Mrs. John J. Ide to honor the memory of her father, the late William H. Donner. These are prize awards for the freshman year, carrying a stipend of $2,200, and are limited to students who are planning to study aeronautical engineering.

East Bridgewater Scholarship (1932)
Established by the Institute through a bequest from Horace T. Smith '98, this grant is known as the Horace T. Smith Scholarship Fund. A scholarship carrying a stipend depending on demonstrated need, with a maximum of full tuition for the freshman year, is annually offered a graduate of the High School of East Bridgewater, Massachusetts.

Elks Scholarship (1959)
This grant from the Massachusetts Elks Association, Inc., for study in science or engineering, is open to residents of Massachusetts who are citizens of the United States and who wish to follow a course in either of these fields on completion of secondary school. The award is designed to assist an individual of excellent character, good health, first-rate academic promise, and with qualities of leadership. Stipends are determined on demonstrated need up to a maximum of $2,500 annually. Grants are on annual application renewable depending on achievement and financial need for the second and succeeding years, or a total of four years.

Fall River and Swansea Scholarships (1932)
These scholarships were established by the Institute through a bequest of Elizabeth R. Stevens, to be known as grants from the Albert G. Boyden Fund. A limited number of scholarships for the freshman year, carrying stipends based on demonstrated need, are annually offered to qualified applicants residing in Fall River or Swansea, Massachusetts.

Freshman Competitive Scholarships (1932)
These awards cover part tuition for the first year. There are no geographical restrictions of eligibility, and any candidate for admission to the freshman class directly from secondary school may apply. Competition is based upon academic records and evidences of non-academic merit of the competitors, and no special examinations are required.

General Motors Scholarships (1955)
These four-year grants, established under the General Motors College Scholarship Plan, are open to citizens of the United States and are intended for outstanding individuals. Five awards are made to entering first-year students. Stipends will be fixed on the basis of demonstrated need.

Humphrey M. Haley Scholarship Fund (1958)
This bequest of Humphrey M. Haley '04 is held in trust and the income used as scholarship aid to one or more deserving students, with first preference to students residing in the St. James Parish in Salem, Massachusetts.

Charles Hayden Memorial Scholarships (1939)
Established through a grant from the Charles Hayden Foundation, these scholarship awards are in memory of the late Charles Hayden, a graduate of the English High School Class of 1886 and of the M.I.T. Class of 1890.

Jakobson Scholarship (1951)
Established by Jakobson Shipyard, Inc., this annual freshman scholarship carries a grant of $1,000. First preference is given to a son of an employee of Jakobson Shipyard, Inc.; second preference is to graduates of the following New York high schools: Glen Cove, Huntington, Manhasset, Oyster Bay, Port Washington, Roslyn, Sea Cliff; and third preference is to secondary school graduates who reside on Long Island, excepting the counties of Kings or Queens.

Knapp Memorial Scholarships (1951)
Gift of the Knapp Fund, these scholarships are for students entering M.I.T. from the Buffalo area and Erie County. Applicants will be expected to have demonstrated good ability and achievement in their secondary school performance, show need of financial aid, and evidence an active interest in their school and community. Selection will be made by a committee from the M.I.T. Alumni Club of Buffalo and the Director of Student Aid.

Amelia S. Kniesner Scholarship Fund (1944)
Gift of William T. Kniesner '16 and his sisters, the income is used "to provide scholarship aid to meritorious or needy students, either entering freshmen or undergraduate students of the Institute, preference to be given to graduates of the high school or high schools of Danbury, Connecticut."

Jacob and Jennie Lichter Fund (1949)
This scholarship fund is "for the aid of students who shall satisfy all entrance requirements of the Institute and be endorsed as to character and personality."

Littmann Foundation Scholarship (1960)
This four-year grant, supplied by the Littmann Foundation, is available in alternate years to a male student desiring to pursue a course of study either in engineering or management as related ultimately to manufacturing. First preference in the selection is given to a well-qualified secondary-school graduate, resident either in the general area of St. Louis, Missouri or Charles City, Iowa. The amount of the award is based on demonstrated need up to the amount of tuition.

Charles E. Locke Memorial Fund (1923)
Preference in making awards from this fund, which was established by the Class of 1896, is given to descendants of members of the Class of 1896, including freshmen.

George J. Loveley Scholarship Fund (1960)
The income of this fund is used to assist needy students, with first preference to sons of widows, whose fathers were native born citizens of Massachusetts, preferably of Boston and vicinity.

H. W. McCurdy Scholarship (1957)
Established by the Puget Sound Foundation in honor of H. W. McCurdy '22, this gift provides one scholarship for an entering freshman who plans to follow a career in naval architecture or mechanical engineering. Preference will be given to a student from the Seattle area.

Eugene and Margaret McDermott Scholarship Fund (1960)
The income of this fund, established by Mr. and Mrs. McDermott, is used for four-year scholarship grants for students resident in the southwest who wish to study in the earth sciences and allied fields. First preference is given to students resident in Texas, with the next preference to Arizona, New Mexico, or Oklahoma. Grants vary from an honorary award of $200 to a maximum of $2,500.

Martin Aircraft Scholarship (1954)
This endowment of $25,000 establishes scholarships for male students planning to pursue Courses most applicable to the activities of The Glenn L. Martin Company. Preference will be given to residents of Maryland (including the District of Columbia) and special consideration will be given to sons of employees of The Glenn L. Martin Company.

Waldo A. Martin Scholarship Fund (1950)
This fund was established by Eleanor P. Martin in memory of her brother, Waldo A. Martin '90. Until 1975 first preference in awards is to be given to friends or relatives of Waldo A. Martin and the donor, and second preference to graduates of Milton High School, Milton Academy, or a resident of Milton. Awards are for the freshman year only, on the basis of character, integrity, and ability.

George H. May Fund (1914)
A gift of $5,000 from George H. May '92 provides a scholarship "to assist graduates of the Newton High Schools who are students at M.I.T. and who have been recommended as eligible by the Superintendent and Head Master of the Newton High Schools." Beneficiaries under this fund are expected to issue notes agreeing to repay, without interest, the amounts received.

Milton High School Fund (1885)
Founded by the Institute in recognition of contributions from residents of Milton, this scholarship is conferred upon such former pupils of the Milton High School in good standing at the Institute as the Master of that school and the School Committee of the town may select.

Joseph R. Minevitch Memorial Scholarship Fund (1957)
This bequest of Joseph R. Minevitch '16, in the name of his mother, Fannie Minevitch, and his brother, Borrah Minevitch, is to assist deserving young men or women with first preference to graduates of the Boston English High School, second preference to graduates of any Boston public high school, and third preference to graduates of any other public high school in the United States.

M.I.T. Alumni Fund National Scholarships (1957)
These four-year scholarships were established by the M.I.T. Alumni Fund Board to give opportunity to well-qualified young people in the continental United States to come to the Institute. Grants are made on the basis of demonstrated financial need, and continued awards depend upon achievement as well as need for assistance.

M.I.T. Boston Stein Club — New England National Scholarship Fund (1955)
The income of this fund is granted to qualified applicants for the freshman year only. One or more awards are available to New England residents as well as to residents of other parts of the United States. There are no restrictions as to sex, religion, race, or color.

M.I.T. Club of Chicago Scholarship Fund (1944)
This gift of $6,000 was made by Harold B. Harvey '07, "to establish scholarships to be known as the Technology Club of Chicago Scholarship Fund," the awards to be made by a committee composed of the Honorary Secretaries of the Chicago area and the Director of Student Aid, and restricted "to boys who reside in the area of the club membership."

Naval Architecture and Marine Engineering Scholarships (1957)
These grants were established by the Society of Naval Architects and Marine Engineers. One scholarship in the amount of $1,000 is awarded each year to a secondary school graduate in the United States who plans to enter the field of naval architecture and marine engineering and who gives promise of extraordinary talent and ability. Each grant may be renewed for three additional years.

Niarchos Scholarship (1956)
Established by Stavros S. Niarchos as a memorial for merchant mariners who gave their lives during World War II, these grants provide opportunities for higher education to the sons of merchant seamen. The awards are based upon demonstrated need and achievement in secondary school experience. Holders of these scholarships are given opportunities to work in the marine field during summer vacations as part of their total education. In the selection of candidates, first preference is given to sons of merchant seamen and ships' officers who lost their lives in the line of duty during wartime. In other cases, candidates' fathers must be regularly employed in a seagoing capacity or, if deceased, so last employed. These awards are not limited to Courses in marine engineering and naval architecture, but consideration may be given to the desire of qualified candidates to pursue careers in these fields.

Procter and Gamble Scholarship (1955)
Two four-year scholarships, open to entering students, are sponsored by the Procter and Gamble Fund. One student following a science Course and one student following an engineering Course are chosen each year. Grants cover tuition plus an added amount for books and supplies.

Willis Ward Reeves, Jr., Fund (1945)
Established by Mr. and Mrs. Willis Ward Reeves of Hazard, Kentucky, "as a memorial to their son, Willis Ward Reeves, Jr., '46, late Lieutenant, U.S. Army Air Forces, killed in action over France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Kentucky."

William Barton Rogers Scholarships (1947)
A limited number of four-year grants established in honor of William Barton Rogers, founder of the Institute, enable young men of superior ability and future promise but of limited financial means to pursue an education in either engineering, science, or architecture. A stipend of $1,800 (full tuition plus $300) is granted for the first year. Successful applicants who maintain honor standing continue to hold full-tuition awards for their undergraduate course and are eligible to apply to borrow up to the amount of tuition annually from the Technology Loan Fund. These scholarships are open to all freshmen with no restrictions of geographical location.

Frederick J. Shepard Fund (1959)
Income from the gift of the Lewis-Shepard Fund in honor of Frederick J. Shepard, Jr. '12, is used to assist needy and worthy young men from New Hampshire, with first preference to graduates of Pinkerton Academy in Derry Village.

Frank Arnold Sherman Scholarship Fund (1947)
The income from this bequest of Frank Arnold Sherman '03, is used "first and preferentially for a scholarship to some boy graduate of Westerly High School, Rhode Island, or if no suitable candidate, preferentially to a boy graduate of some other Rhode Island high school."

Sloan National Scholarships (1953)
Established by the Alfred P. Sloan Foundation, Inc., these scholarships provide aid for students in science and engineering and are open to male students resident throughout the continental United States. Sloan National Scholars hold positions of academic honor at the Institute. Awards are made to men of high character, sound personality, leadership potential, and academic promise. Grants range from a $200 prize scholarship to $2,000 per annum. Awards are renewable each year, subject to performance and in accordance with changing financial need.

G. H. Miller Smith Fund (1945)
Established by Mr. and Mrs. George Blackwell Smith of Lookout Mountain, Tennessee, "as a memorial to their son, G. H. Miller Smith '43, late Lieutenant, U.S. Army, killed in action in France during World War II . . . the income to be used for scholarship aid to deserving undergraduate students, with preference to those from Tennessee."

Albert F. Sulzer Scholarship (1955)
Established under the will of Albert F. Sulzer, this fund is "to be used by the trustees of the Massachusetts Institute of Technology for the establishment and maintenance of scholarships for meritorious first-year students who are non-residents of the State of Massachusetts."

Tau Beta Pi Memorial Scholarship Fund (1947)
This gift from members of Tau Beta Pi, Massachusetts Beta Chapter, on their twenty-fifth anniversary, provides an annual award of $500 for freshmen to be selected by the M.I.T. Student Financial Aid Committee. There is no restriction of geographical area, and candidates are selected on high scholastic standing, character, and future promise.

Union Carbide Engineering Scholarships (1960)
This grant from the Union Carbide Educational Fund is used for four-year tuition grants in either mechanical, chemical, or metallurgical engineering.

Vermont Scholarship (1924)
This scholarship "in memory of Vermonters who, having received their education at the Institute, served as engineers in the Armies of the Allies in the World War," was founded by a gift of $76,000 from Redfield Proctor '02. The income is awarded annually "to worthy students . . . preference to any *bona fide* residents of Vermont doing undergraduate work at the Institute, and also Vermont students doing graduate work, or students who are graduates of or transfer from Middlebury College or Norwich University . . . who shall meet regular scholastic and other requirements."

Henry E. Warren Fund (1961)
As a memorial to Henry E. Warren '94, the Trustees of the Warren Benevolent Fund, Inc., contribute to the support of a limited number of entering freshmen. Grants are made by the Committee on Student Financial Aid to students who demonstrate financial need. The Committee gives first preference to well-qualified students domiciled in New England and second preference to women students from any part of the United States or its possessions. It is hoped that beneficiaries of this fund will make contributions to the Warren Fund after graduating, so that other students may benefit from it.

Granger Whitney Fund (1957)
Income of this bequest, made by the will of Julia Whitney in the name of Granger Whitney '87, is used to assist worthy students of the Institute, with first preference being given to students nominated by the Detroit M.I.T. alumni club.

Arthur Williams Scholarship in Engineering (1958)
Established by the Trustee under the will of the late Arthur Williams of Roslyn, Long Island, this scholarship is used to assist one or more needy and deserving young men to qualify in the engineering professions and business administration.

SCHOLARSHIPS FOR UPPERCLASSMEN

The Institute holds several funds from which the income is used to make awards to students in the upper undergraduate years. It is the policy of the Student Financial Aid Committee to assist as many well-qualified students as possible by assigning, in general, amounts less than full tuition. Awards are made only to students who have completed at least one year of satisfactory work at the Institute. The ability of the student, as indicated by his scholastic record, is the primary consideration in making selections. However, account is also taken of the applicant's evidence of need for financial assistance, of his good character, and of his general worthiness and professional promise. Applications should, except as noted below, be made on blanks to be obtained at the Student Aid Center, Room 5-119.

The scholarships or funds described are arranged in the alphabetical order of their names, the figures in parentheses being the dates of establishment.

Frank W. and Carl S. Adams Memorial Fund (1955)
Established by Mr. and Mrs. Charles E. Adams, with The First National Bank of Boston as Trustee, and named in memory of their two sons as the Frank W. and Carl S. Adams Memorial Fund, this fund is used to assist needy and deserving students at M.I.T. A limited amount may also be available to assist an impecunious student who is unable to participate in recognized functions incident to graduation.

American Machine & Foundry Company Scholarship (1960)
This two-year grant of $750 is awarded annually to a member of the junior class majoring in mechanical or electrical engineering. Recipients are chosen on the basis of academic achievement, demonstrated need, extracurricular activities, leadership, and citizenship. Preference is given to residents of New England, New Jersey, New York, and Pennsylvania.

American Smelting and Refining Company Scholarships (1946)
This gift of the Company was made to establish a scholarship of $500 to a student in metallurgy, with preference to third- or fourth-year students.

American Society for Metals Award (1954)
A grant of $500 is awarded annually to a second-year student in metallurgy under this scholarship. Selection is made on the recommendation of the Department of Metallurgy to the Student Financial Aid Committee from among students who have applied for assistance for the sophomore year and who have demonstrated good ability and need.

Anonymous (1948)
This gift of an alumnus is used for scholarship purposes.

Anonymous P (1959)
This gift is to assist needy and worthy students.

Louie G. Applebee Fund (1942)
This bequest is "to be expended in assisting deserving students."

Elisha Atkins Fund (1894)
This fund was established by Mrs. Mary E. Atkins of Boston with a gift of $5,000.

Julian M. Avery Fund (1957)
Established by Julian M. Avery '18, this fund is designated for undergraduate scholarships in metallurgy.

Jason S. Bailey Fund (1952)
Established by the estate of Jason S. Bailey, this fund is used for undergraduate scholarships at the Institute.

Thomas Wendell Bailey Fund (1914)
The income from this bequest of Thomas Wendell Bailey is used to assist "needy students in the Department of Architecture."

Charles Tidd Baker Fund (1922)
One-half of the net income of this bequest of $20,000 from Charles Tidd Baker is "applied each year to the assistance of poor and worthy students."

Bechtel Corporation Scholarships (1957)
Two undergraduate scholarships carrying grants of half tuition are awarded seniors in chemical engineering who are nominated by the department and by the Committee on Student Financial Aid.

Alf K. Berle Memorial Scholarship Fund (1960)
Income of this fund, established by his wife in memory of Alf K. Berle '27, is used to assist worthy and needy young men at M.I.T.

Billings Student Fund (1900)
A bequest of $50,000 from Robert C. Billings founded the Billings Student Fund. "Any student receiving benefit from this fund is expected to abstain from the use of alcohol or tobacco in any of their varied forms."

Huse Templeton Blanchard Fund (1946)
This bequest of Huse T. Blanchard '01 is for "the benefit of worthy boys of the State of New Hampshire."

Levi Boles Fund (1915)
The net income of this bequest of $10,000 from Frank W. Boles in memory of his father, Levi Boles, is "applied annually to the assistance of needy and deserving students."

Jonathan Bourne Fund (1915)
This bequest of $10,000 from Hannah B. Abbe constitutes a fund "known as the Jonathan Bourne Scholarship Fund, the income only to be used in aid of deserving students."

Albert G. Boyden Fund (1931)
This bequest of $40,000 from Elizabeth R. Stevens is a permanent fund, known as the Albert G. Boyden Fund, "income only to be awarded as scholarships to assist worthy and needy students, preference to be given to young men or women residents of the town of Swansea or the city of Fall River."

Bertram Brewer Scholarships (1952)
The income from this bequest under the will of Bertram Brewer is used "to provide annual scholarships for deserving undergraduates of good character and ability. . . ."

Harriet L. Brown Fund (1932)
This bequest of Harriet L. Brown is "to be held in trust as a scholarship . . . the income to be given to such needy and deserving young women desiring to become students at M.I.T., as would otherwise be unable to attend; and in case of two or more applicants of equal merit, preference shall be given to a native of either Massachusetts or New Hampshire."

Cabot Endowed Scholarship (1955)
The income from this endowment, a gift of Godfrey L. Cabot, Inc., is used as scholarships for undergraduate students of the Institute in accordance with the general Institute practices and procedures.

Godfrey L. Cabot Fund (1950)
Scholarships made possible by this gift are awarded with preference to students of chemistry or chemical engineering.

Thomas D. Cabot Scholarship Fund (1950)
Two-thirds of the income of this fund, established by Mr. and Mrs. Thomas D. Cabot, is used to assist worthy students with financial aid; and one-third is used for salaries for teachers.

Mabel Blake Case Fund (1920)
This bequest of $25,000 from Caroline S. Freeman is "known as Mabel Blake Case Fund, income to be used to aid deserving students (preferably women) who are in need of assistance."

Nino Tesher Catlin Fund (1926)
A gift from Maria T. Catlin established this fund in memory of her son, Nino T. Catlin '18, the income "to be awarded to needy and deserving students."

Chemical Club of New England Fund (1955)
This annual grant, established by the Chemical Club of New England, is designed to promote interest in work in chemistry or chemical engineering in New England. It is open to junior and senior students who are residents of New England who are majoring in chemistry or chemical engineering, and who have demonstrated substantial academic achievement and financial need.

Lucius Clapp Fund (1905)
This gift from Lucius Clapp formed a fund "to aid worthy students who may not br able to complete their studies without help."

Thomas L. Clark Memorial Scholarship (1956)
The income from this endowment, established in memory of Thomas Lynn Clark '59, by a number of his friends at M.I.T., is used to assist a worthy and needy student at the Institute as determined by the Student Financial Aid Committee.

A. V. Clarke Fund (1950)
The proceeds of this gift by Mr. Clarke are "used for student aid at the discretion of the Student Financial Aid Committee."

Class of 1909 Memorial Fund (1957)
The income of this fund, initiated by gift from the widow of Carl W. Gram '09, and augmented by subsequent gifts in memory of Felix A. Burton, James H. Critchett, Benjamin W. Dow, Harold I. Eaton, Harry L. Havens, Reginald L. Jones, George A. Haynes, Helen Longworth Paul, William R. Reilly, and Clark S. Robinson, all members of this class, is used for scholarship aid, with first preference to descendants of members of the Class of 1909.

Fred L. and Florence L. Coburn Fund (1932)
The income of this bequest of $5,000 from Fred L. Coburn "shall be expended by said Trustees in giving aid and assistance to students of M.I.T. . . . preference being given by said Trustees to students residing in Somerville, Massachusetts."

Coffin Memorial Fund (1929)
This gift from the executors of the estate of Charles A. Coffin — a bequest — carried out the wishes of Mr. Coffin. The fund is used for loans or other aid to students as determined by the Executive Committee of the Corporation.

College of William and Mary Scholarship (1904)
Established by the Institute in commemoration of the early association of President William Barton Rogers with the College of William and Mary, this scholarship provides a stipend of $400 per year; it is granted to a student nominated by the faculty of the College of William and Mary.

Albert Conro Scholarship Fund (1943)
This bequest of Mary T. Conro, sister of Emma O. Conro '84, in memory of their uncle, is "for the purpose of establishing and maintaining a scholarship . . . to be known as the Albert Conro Scholarship."

The George R. Cooke Fund (1939)
Established by a gift in memory of George R. Cooke '08, the income of this fund is awarded preferably to a student in civil engineering or a related field. Consideration is given to those who have had experience through employment in a field before undertaking formal study; the recipient need not necessarily be a candidate for a degree. Grants will be based on character, achievement, need, and future promise.

John G. Crane Scholarships (1951)
This gift of J. G. Crane '90 is for undergraduate awards.

Allen S. Crocker Memorial Fund (1961)
The income of this fund, established as a memorial by the wife of Allen S. Crocker '97, is used to assist worthy and needy young men. Stipendiary awards will be according to demonstrated financial need up to a maximum of tuition in any one year. First preference in the selection is given to students domiciled in the Rochester, New York area. Any unused income from this fund in any one year shall revert to the principal of the fund.

Lucretia Crocker Fund (1916)
By the will of Matilda H. Crocker, the Institute was made the residuary legatee of her estate "for the establishment of one or more scholarships for women in memory of my sister, Lucretia Crocker . . . the income to aid one or more young women in need of pecuniary assistance in obtaining instruction at said Institute."

Eunice McLellan Cruft Fund (1949)
This bequest of Eunice McLellan Cruft was made "to assist young men whose means are inadequate to pay their expenses at the Institute."

Isaac W. Danforth Fund (1903)
This bequest of $5,000 from James H. Danforth for scholarship purposes was a memorial to his brother, Isaac Warren Danforth.

The Delafield Memorial Fund (1960)
This fund was established by the parents of Benjamin T. Delafield '60 to be used to assist needy and deserving students at M.I.T. and at the discretion and judgment of the Director of Student Aid.

Orville B. Denison Memorial Fund (1960)
The income of this fund, donated by the members of the Class of 1911 as a memorial to Orville B. Denison '11, is used to assist worthy and needy undergraduates at the Institute.

Carl Pullen Dennett Memorial Scholarship Fund (1956)
Established by a gift in memory of Carl Pullen Dennett, this fund provides an award for students in the School of Science, either graduate or undergraduate, who are deemed qualified by scholastic performance, intelligence, character, and promise. The annual selections are made by the Director of Student Aid and the Dean of Students.

Thomas C. Desmond Scholarship Fund (1960)
The income of this gift of Thomas C. Desmond '09 is awarded to deserving undergraduates at the Institute in accordance with the general policies of the Institute.

Ann White Dickinson Fund (1898)
This bequest of $40,000 from Ann White Dickinson was made "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

Fred C. Dobbs Fund (1960)
The income of this fund, established in the name of Dr. F. C. Dobbs by his friends, is used to assist undergraduates to meet their expenses at the Institute. Selection is limited to citizens of the United States who have demonstrated a need for financial assistance and have given evidence of promise.

Dormitory Fund (1903)
This fund was raised by miscellaneous subscriptions; it was formerly known as Students' Aid Fund.

Thomas Messinger Drown Scholarships (1928)
A bequest of $50,000 from Mary Frances Drown was designated "to establish scholarships for deserving undergraduate students, to be known as the Thomas Messinger Drown Scholarships."

Edgerton, Germeshausen and Grier, Inc., Scholarships (1955)
This gift funds scholarships, preferably for students in electrical engineering.

William Emerson Fund (1959)
The income of the bequest of the late William Emerson, Dean of the School of Architecture, is used for scholarships in the Department of Architecture.

Farnsworth Fund (1889)
This fund was founded by Mrs. Mary E. Atkins of Boston with a gift of $5,000.

Charles Lewis Flint Fund (1889)
This bequest of $5,000 from Charles L. Flint is for the "support of some worthy student, preference to be given to some graduate of the English High School, Boston."

Sarah S. Forbes Fund (1913)
Originally a fund of $2,800 given in trust in 1868 by Sarah S. Forbes to William Barton Rogers and Henry S. Russell, trustees, this fund was transferred in 1913 to the Institute "for the maintenance and education of a scholar in M.I.T."

Clara and F. Joseph Ford Scholarship (1951)
The income of a fund established by Mr. and Mrs. Joseph F. Ford is awarded "to worthy and well-qualified students who have demonstrated a democratic and tolerant spirit and who are well disposed toward people of all creeds and races."

Foundry Educational Foundation Scholarships (1947)
Established by the Foundry Educational Foundation, which represents the American Foundrymen's Association, the Gray Iron Founders' Society and the Malleable Founders' Society, and the Foundry Equipment Manufacturers Association, these awards are open to third- and fourth-year students in business and engineering administration, mechanical engineering, and metallurgy.

Arthur E. Fowle Fund (1956)
The income of this fund established under the will of Arthur E. Fowle '93 is to be used for undergraduate scholarships.

Evert W. Freeman Scholarship Fund (1956)
The income of this fund, established by bequest of Evert W. Freeman '20, "shall be awarded annually to a student . . . who shows promise of substantial accomplishment but is in financial need "

Philip Jacob Friedlander Fund (1945)
This fund was the gift of Israel Friedlander "in appreciation of the opportunity my son, Philip Jacob Friedlander, had of spending a little more than a year at M.I.T. before enlisting in the United States Naval Reserve . . . the income to be used with the income from other such funds for the purpose of helping qualified students at M.I.T. regardless of race, creed, or color, or geographical origin, who may be in need of financial assistance . . ."

Jurgis J. Geguzis Fund (1957)
Established under the will of the late Jurgis J. Geguzis, this fund is to be used for tuition and expenses for a student of Lithuanian parentage. The recipient is selected by the Institute upon the condition that he shall repay the amount of his award "when and if able so that other students may be granted the same benefits and privileges in the future."

Norman H. George Fund (1919)
This bequest of Norman H. George is "to be used for the assistance of needy and worthy students in obtaining an education in M.I.T."

Arthur B. Gilmore Fund (1941)
This bequest of $10,000 from Arthur B. Gilmore is ". . . for the purpose of assisting needy students who shall be members of the Beta Theta Pi fraternity . . . said net income to be divided among not more than two students in any one year."

James R. Glazebrook Fund (1959)
The income of this fund is to be used to assist needy and worthy undergraduates at the Institute.

Goodyear Scholarship (1957)
A stipend of $1,000 made available by the Goodyear Foundation, Inc. is granted to a male U.S. citizen majoring in engineering in his junior or senior year. Awards will be made on the basis of academic standing, character and leadership qualities, and financial need.

Barnett D. Gordon Fund (1942)
The income from this gift of $21,000 from Barnett D. Gordon '16 is to be used "as scholarships for deserving students at M.I.T."

John A. Grimmons Fund (1952)
This fund was established by the estate of Katie M. A. Grimmons in memory of her son, John A. Grimmons '21. The income is to be used for scholarships for students . . . with preference to those in the Department of Electrical Engineering.

William T. Haebler Memorial Scholarship (1960)
This fund was established by his daughter in memory of her father, William T. Haebler '22. The income is used to assist worthy and needy students who are undergraduates and are citizens of the United States.

Lucia G. Hall Scholarships (1945)
The income from this bequest of Louise K. Gunn, to "be known as 'The Lucia G. Hall Scholarships' . . . is to be used for the aid of worthy students."

Hall-Mercer Scholarship Fund (1940)
The income from this bequest of Alexander G. Mercer is to be used "for the benefit of such poor students as have passed through some of the public schools with the best reputation for character and ability."

James H. Haste Fund (1930)
This bequest of James H. Haste '96 is "for the aid of deserving students . . . of insufficient means."

Bancroft Hill Memorial Fund (1957)
This fund was established by Frances G. Hill in memory of her husband, Bancroft Hill '11. The income is used for scholarship assistance to students in civil engineering who are in need of financial help.

George Hollingsworth Scholarship (1916)
A bequest of $5,000 from Rose Hollingsworth founded this George Hollingsworth Scholarship.

Loren C. Holm Scholarship Fund (1950)
Established by Marie Holm in memory of her father, this fund is designated for worthy and needy students.

Elias Howe, Jr., Scholarships (1949)
The income from a fund established under the will of Julia Howe Stockwell Smith "shall be available for aiding such students and in such amounts as shall be recommended by the Faculty."

Samuel P. Hunt Fund (1945)
This gift of Samuel P. Hunt '95 was designated for scholarship purposes.

T. Sterry Hunt Scholarship (1894)
A bequest of $3,000 from T. Sterry Hunt, for seven years Professor of Geology at M.I.T., was designated to found a scholarship in his name. The award is restricted to students in chemistry, and preference is given to those in the higher years.

William F. Huntington Fund (1892)
From Susan E. Covell the Institute received a gift of $5,000 to constitute a fund in memory of William F. Huntington '75, the "income to apply to payments of tuition of needy and deserving students . . . preference to be given to students in civil engineering."

Charles L. Ireson Scholarship Fund (1959)
Income of this fund, established by the will of Jennie E. Ireson, is devoted to the education of worthy students who may require financial assistance.

I-T-E Foundation Scholarship (1952)
Established by the Harrison Jules Louis Frank and Leon Harrison Frank Memorial Corporation in memory of the founders of the Bulldog Electric Products Company, this $700 scholarship is designated for a needy and worthy junior or senior in electrical engineering who is interested in the field of distribution and/or control of electricity.

David L. Jewell Fund (1928)
The income from this bequest of $25,000 from Colonel David L. Jewell is "to be used to pay part of the tuition charges for five young men who may be selected by the President or Board of Trustees of the Institute as worthy of assistance, and who, were it not for such assistance, might be unable to pursue their studies at such Institute."

Edward A. Jones Scholarship Fund (1947)
A bequest of $25,000 from Edward A. Jones was designated "to be used for the establishment and maintenance of one or more scholarships."

Joy Scholarship (1886)
Established by the gift of Nabby Joy, this scholarship was created pursuant to a decree of the Supreme Judicial Court of Massachusetts for the benefit of "one or more women studying Natural Science at M.I.T."

Sarah Maude Kaemmerling Fund (1952)
This fund was established by a gift of $20,000 in 1952 and subsequently added to by a testamentary bequest in 1959. The income is used for scholarships or some alternate form of student aid.

William R. Kales Scholarship Fund (1953)
This fund, endowed by a gift of the Whitehead and Kales Company for scholarship purposes, provides income to assist worthy and needy undergraduates.

Kennecott Copper Corporation Scholarship (1954)
Established by the Corporation, this scholarship is open to incoming seniors in business and engineering administration or mechanical engineering. Selection is made by the Student Financial Aid Committee on recommendation of candidates by the Departments, in cooperation with a representative of the company.

Bo Kwang Kim Scholarship Fund (1957)
Established under the will of Bo Kwang Kim, this scholarship is for students of complete Korean ancestry. It is open to any deserving and needy Korean students. An award of $500 is made only when the income of the Fund permits.

Kollsman Instrument Fund Scholarships (1961)
Four annual awards are established by the Kollsman Instrument Company for undergraduates in the Schools of Engineering and Science.

Kurrelmeyer Fund (1947)
This fund was raised by contributions "for an undergraduate scholarship award to a needy student."

Y. T. Li Fund (1959)
The income of this fund, established by Y. T. Li '38, is used to assist a worthy and needy student enrolled in the Department of Aeronautics and Astronautics; second preference is given to a student of Chinese origin.

Gustaf Robert Lindberg Fund (1957)
This fund was established by Otto C. Lindberg, President of the General Drafting Company, to create the Gustaf Robert Lindberg Scholarships. The income is used for scholarships "that shall provide tuition, board and other necessary expenses preferably to one or more students who are citizens and residents of . . . Finland; second preference to citizens and residents of Sweden. If no worthy candidates from either Finland or Sweden, the scholarships may be awarded to the best qualified candidates who are citizens of the United States preferably of Finnish or Swedish extraction."

Paul Weeks Litchfield Scholarship (1954)
Established in honor of Paul W. Litchfield '96, this scholarship fund aids worthy and needy students at the Institute. Preference in selection is given to those students who have been members of the Boy Scouts of America.

William Litchfield Scholarship (1910)
A bequest of $5,000 from William Litchfield established "a single scholarship . . . known as William Litchfield Scholarship, income to be awarded and paid annually to such student in said Institute as may, upon a competitive examination, be determined by the President of said Institute to be entitled thereto for excellence in scholarship and conduct."

Richard W. Lodge Fund (1955)
The income of this fund, established by the will of Mary L. Lodge in memory of Richard W. Lodge '79, is used for worthy and needy students.

Elisha T. Loring Fund (1890)
This bequest of $5,000 from Elisha Thacker Loring is for "the assistance of needy and deserving pupils."

Lowell Institute Fund (1923)
Gifts from the alumni of the Lowell Institute School founded this fund, the income of which is annually awarded to assist some graduate of that School who desires to enter upon undergraduate studies at M.I.T. Applications must be filed at the Office of the Director of Student Aid.

Percival Lowell Scholarships (1955)
The income of this gift is used for scholarships awarded from time to time at the discretion of the President of the Massachusetts Institute of Technology to students in astronomy, physics, and mathematics.

Alice Maclaurin Scholarship (1951)
Gifts created a scholarship in memory of Mrs. Richard C. Maclaurin.

Francisco Marcucella Fund (1953)
This gift of Francisco Marcucella '27 was designated for scholarship purposes.

Rupert Anderson Marden Fund (1933)
This fund was established by an anonymous gift "toward a memorial to be known as the Rupert Anderson Marden Scholarship Fund, income available annually to aid a worthy student at M.I.T. — Protestant and of American origin — preference to a student taking the Cooperative Course in Electrical Engineering."

Margaret A. Matthews Fund (1947)
The income of this bequest from Margaret A. Matthews is "for the benefit of such of the women students at M.I.T. who intend to become teachers."

George J. Mead Prize Scholarships (1951)
This bequest of George J. Mead '16 established prize scholarships in aircraft propulsion open to juniors, seniors, and graduate students in this field. Consideration is also given to candidates from related engineering fields as applied to aircraft propulsion. Recommendation is made by the Department of Aeronautics and Astronautics to the Student Financial Aid Committee.

Charles E. Merrill Scholarship Fund (1955)
The gift of Charles E. Merrill, this fund is for "students having financial need . . . who have demonstrated through personality traits, initiative, or by scholastic achievement that they will become substantial democratic citizens." One-half the income is used to meet the overhead expense of the Institute.

Arthur Merkel Miller Fund (1960)
Income of this fund, established by the will of Arthur Merkel Miller '17, is to provide scholarship assistance to worthy students.

Robert W. Milne Fund (1943)
This bequest of $70,000 was made as "an endowment fund under the title of 'The Robert W. Milne Fund,' the income thereof to be used and applied for the assistance of worthy and needy students in obtaining an education in said Institute."

James H. Mirrlees Fund (1886)
This gift of $2,500 from James Buchanan Mirrlees of Glasgow, Scotland, constituted a scholarship in memory of his son, James Henry Mirrlees, who died in 1886 while attending the Institute. The income is awarded to the "student in the third or fourth year of the Mechanical Engineering Course most deserving pecuniary assistance."

Morningstar Scholarship (1953)
This undergraduate scholarship gives first preference to students in the Physics Department. Grants are equivalent to one term's tuition and are continued to a recipient for the entire undergraduate period.

Fred W. Morrill Scholarship Fund (1941)
The income from this bequest of Hattie B. Morrill is to be used "for the purpose of providing financial assistance to some student or students at the discretion of the Trustees of said Institute. . . ."

Frederick Taft Moses Scholarship Fund (1959)
This scholarship provides four-year awards ranging from a $200 honorary prize to $2,000 annually, and is offered to young people of superior talent and promise.

Naval Architecture and Marine Engineering Scholarships (1953)
Two scholarships, established by gift of the Gulf and South American Steamship Company, are awarded annually: 1) to assist students who plan to spend the fifth year in Shipping and Shipbuilding (Course XIII-B); and 2) an annual scholarship for secondary school graduates who plan to go into the field of naval architecture and marine engineering. Selection will be made by the Department of Naval Architecture and Marine Engineering and the Student Financial Aid Committee.

Gertrude B. Newman Scholarship (1952)
This bequest from the estate of Mrs. Gertrude B. Newman is to aid worthy and deserving students.

Nichols Scholarship (1895)
This bequest of $5,000 from Mrs. Betsy F. W. Nichols constitutes the Nichols Scholarship in memory of her son, William Ripley Nichols '69, for sixteen years Professor of General Chemistry at the Institute. Preference is given to students in the Course in Chemistry.

Charles C. Nichols Scholarship (1904)
This bequest of $5,000 from Charles C. Nichols constitutes a scholarship.

William E. Nickerson Scholarship Fund (1949)
The income from this fund, established by the Nickerson Trust, is used for a scholarship for a worthy student.

Howard A. Noble Scholarships (1955)
The income from a fund established under the will of Katherine B. Noble is used to maintain one or more scholarships in engineering.

John Felt Osgood Scholarship (1909)
This bequest of $5,000 was made by Elizabeth P. Osgood "to establish and maintain a scholarship in electricity in memory of my husband, John Felt Osgood."

Louise Parks Knight and Charles F. Parks Memorial Fund (1952)
Established as a memorial to Louise Parks Knight and her father, Charles F. Parks '75, this fund is "used for the aid of poor but worthy students who have already entered upon a course of study but are unable to finish owing to lack of funds."

George L. Parmelee Fund (1921)
This bequest from George L. Parmelee of "one third of my property and estate" specified that "interest thereof be used for tuition of worthy students, either special or regular, according to the direction of the Faculty."

Langdon Pearse Memorial Scholarship (1958)
This fund was established by gift of Mrs. Langdon Pearse in memory of Langdon Pearse '01. Income from the fund is used toward the tuition of graduate students in the field of sanitary engineering, with second preference for undergraduate students in the field of civil engineering.

Frank Stetson Pecker Fund (1947)
This fund was established by the wills of Frank Stetson Pecker and Annie J. Pecker for a scholarship.

Richard Perkins Fund (1887)
The income from half of this bequest of $100,000 from Richard Perkins is available for the "support of free scholarships in said Institute."

Charles H. and Helen Bartlett Pray Fund (1950)
Established under the wills of Charles H. and Helen Bartlett Pray, this fund provides "for scholarships for needy young men."

Florence E. Prince Fund (1943)
This bequest of Florence E. Prince is "for the aid of worthy students who may need assistance in the matter of maintenance and living expenses while pursuing their studies."

G. H. Rand Scholarship (1958)
This legacy was established under the will of George H. Rand, and the income is used to assist and benefit deserving students.

Thomas Adelbert Read Scholarship (1934)
This bequest of $10,000 from Julia A. Read was designated "to establish the Thomas Adelbert Read Scholarship, in memory of my late brother of that name; the income of said fund to be awarded to some worthy and needy student of that institution, preferably to a resident of Fall River. . . ."

Charles A. Richard's Fund (1939)
This bequest of approximately $30,000 is "known as the Charles A. Richard's Fund . . . the income only for assistance of poor Protestant students in the Institute."

Frederick L. Richards Memorial Fund (1960)
The income of this fund, established as a memorial to Frederick L. Richards '95 by his sister, is used to provide scholarship assistance to undergraduate students in chemistry, chemical engineering, or other curricula based on chemistry.

John Roach Scholarship Fund (1937)
This bequest of $2,400 from Emeline Roach constitutes a fund "to be known as the John Roach Scholarship Fund, the income to be used to provide an annual scholarship to a needy and deserving student pursuing the Course in Naval Architecture and Marine Engineering."

Karl Robbins Scholarship (1951)
First preference for this scholarship, a gift of the Robbins Foundation, is for either a graduate or undergraduate in textile technology; second preference is to a student in mechanical engineering.

Willard F. Rockwell Scholarship Fund (1961)
The income of this fund, established in honor of Willard F. Rockwell '08, is used to assist needy and worthy undergraduates.

Richard Lee Russel Fund (1904)
The income from this gift of Theodore E. Russel is used to assist a worthy and needy student of high standing in the Department of Civil Engineering, either undergraduate or graduate.

William P. Ryan Memorial Fund (1935)
The income from this fund, established by friends of the late Professor William P. Ryan '18, is used for scholarship aid (graduate or undergraduate) in chemical engineering, the award to be made on recommendation of the Head of the Department of Chemical Engineering.

John P. Schenkl Fund (1922)
This bequest of $20,000 from Johanna Pauline Schenkl is "to be held in trust to establish one or more scholarships in the Department of Mechanical Engineering" in memory of her father, John P. Schenkl.

George Scher Fund (1949)
This gift establishes aid for needy and worthy students.

Science Scholarship (1956)
Donated by friends of M.I.T., this scholarship is designated to assist a needy and promising student in the field of science after the completion of his freshman year. The award is made to citizens of the United States up to the amount of tuition.

Science Teaching Scholarships (1955)
Established by the Institute to encourage young people who wish to follow a career in science teaching in secondary schools, these scholarships are open to students who have completed two years at the Institute and plan to follow a curriculum in science and mathematics teaching. Grants are based on demonstrated need, with a maximum of full tuition.

Paul D. Seghers, Jr., Scholarship (1948)
This award was established by the estate of May Towles Kirk Seghers in memory of Second Lieutenant Paul Dotrenge Seghers, Jr., '45, U.S. Army Corps of Engineers, who was killed in action in the Asiatic area on July 11, 1945, to aid worthy and needy students at the discretion of the Institute.

Irving Shaknov Scholarship (1954)
The income from this fund, established as a memorial for Irving Shaknov '43, is available for an undergraduate scholarship for a student in the Department of Physics.

Frederick J. Shepard, Jr. Fund (1959)
Income from the gift of the Lewis-Shepard Fund in honor of Frederick J. Shepard, Jr., '12, is used to assist needy and worthy young men from New Hampshire with first preference to graduates of Pinkerton Academy in Derry Village.

James and Donald H. Sheridan Scholarships Fund (1961)
The income of this fund, established by the bequest of James Sheridan, is used to aid needy and worthy students.

Thomas Sherwin Scholarship (1871)
Founded with a gift of $5,000 from the English High School Association in memory of Thomas Sherwin, this scholarship is limited to graduates of the English High School of Boston who are pursuing a regular course at the Institute.

H. Hilliard Smith Fund (1950)
This bequest of Grace J. F. Smith in memory of her husband, H. Hilliard Smith '96, is for the purpose of assisting young men in architecture.

Horace T. Smith Fund (1931)
This bequest from Horace T. Smith '98 provides scholarships to worthy students, with preference given to graduates of the East Bridgewater (Massachusetts) and Bridgeport (Connecticut) High Schools.

Sons and Daughters of New England Puritan Colony Scholarship (1931)
Holders of this scholarship, made possible by a gift of $600 from the Sons and Daughters of New England Puritan Colony, must be of New England ancestry.

Anna Spooner Fund (1939)
The income from this bequest of approximately $7,500 is used "in assisting meritorious students."

Wentworth Stevens Fund (1957)
One-half of the income from this fund, established by William Wentworth Stevens '98 in honor of his mother and father, is added to principal; the remainder is made available for scholarship aid.

Texaco Scholarships (1959)
This gift of the Texas Company is to assist worthy and needy students who have completed two years of college work and who have selected a curriculum which will prepare them for a career in the petroleum industry.

Mary Thacher Scholarship (1956)
This bequest established a scholarship fund, the income of which is applied against the tuition of needy students, with first preference to students from Yarmouth, Massachusetts; second to students from the Cape Cod region; and third to students from the Commonwealth of Massachusetts.

Samuel E. Tinkham Fund (1924)
Established by the Boston Society of Civil Engineers, this fund is to aid a worthy student in civil engineering.

F. B. Tough Fund (1924)
This fund was established "for the purpose of extending financial assistance to worthy students." Preference is given to students in mining or oil production.

Arthur L. Townsend Fund (1960)
Income of this fund, established by the bequest of Professor A. L. Townsend '13 of the Department of Mechanical Engineering and Director of Lowell Institute, is used exclusively for M.I.T. scholarships. Preference is given to worthy and well-qualified graduates of Lowell Institute who are in good standing and taking a regular full-time day program, preferably in mechanical or electrical engineering.

Y. T. Tsai Memorial Scholarship (1955)
This fund for worthy and needy students was established by gift.

John L. Turner Fund (1960)
Income of this fund, established by John L. Turner '31, is used to assist needy and worthy young men. First preference is given to students who are direct relatives of the donor or residents of the State of Mississippi; second preference to students domiciled in the Southeast.

United States Rubber Company Foundation Scholarships (1957)
These grants, established by a gift from the United States Rubber Company Foundation, are awarded to students who demonstrate need for financial assistance, who show capacity for higher education, and who are interested in a career in industry. The Foundation expects that beneficiaries will assume a moral obligation to repay a part of their grants after graduation and over a reasonable period of time; such repayments will be made to the Institute's scholarship fund and will then be used to help other needy students.

Susan Upham Fund (1892)
This gift of $1,000 from Susan Upham is "to assist students deserving financial aid."

Samson R. Urbino Fund (1927)
This bequest of $1,000 from Samson R. Urbino is "to be used to aid students who need assistance, Germans preferred."

Vermont Scholarship (1924)
This scholarship "in memory of Vermonters who, having received their education at the Institute, served as engineers in the Armies of the Allies in the World War" was founded by a gift of $76,000 from Redfield Proctor '02. The income is awarded annually "to worthy students . . . preference to any *bona fide* residents of Vermont doing undergraduate work at the Institute, and also Vermont students doing graduate work, or students who are graduates of or transfer from Middlebury College or Norwich University . . . who shall meet regular scholastic and other requirements."

Ann White Vose Fund (1896)
This bequest from Ann White Vose of $25,000 "plus one half of the remainder of my estate" was designated "to establish free scholarships in M.I.T. . . . such persons enjoying benefit . . . shall be worthy young men of American origin."

Arthur M. Waitt Fund (1925)
This bequest of $10,000 from Arthur M. Waitt was designated for "assisting needy and deserving students in the second-, third-, and fourth-year classes of the Mechanical Engineering Course."

Grant Walker Fund (1943)
The income from this bequest of $50,000 is used "for scholarships for deserving students."

Muriel Alvord Ward Fund (1960)
The income of this fund, established by the gift of Mrs. Ferrari P. Ward, is used to assist needy and worthy undergraduates.

James Watt Scholarship (1942)
This bequest of Jennie A. Douglas established "a scholarship in mechanical engineering to be known as the James Watt Scholarship."

Louis Weissbein Fund (1915)
This bequest of $4,000 from Louis Weissbein was designated "to found a scholarship to be awarded each year to a promising student, preference to be given a Jewish boy in making the award."

Western Electric Scholarships (1956)
These two scholarships in engineering, established by the Western Electric Company, are awarded on the basis of need and ability, with a maximum grant of $800.

Westinghouse Air Arm Division Scholarships (1956)
Established by the Westinghouse Electric Corporation, these scholarships provide $500 grants to sophomores in mechanical engineering, electrical engineering, physics, and applied mechanics. Recipients will be offered summer employment at the company's Baltimore plant.

Frances Erving Weston Fund (1912)
This bequest of Frances Erving Weston is "to aid a native-born American Protestant girl of Massachusetts."

Samuel Martin Weston Fund (1912)
This bequest of Frances Erving Weston was made to found a scholarship in memory of her husband, Samuel Martin Weston, "to aid a native-born American Protestant boy, preference to be given one from Roxbury."

Archer E. Wheeler Scholarship Fund (1957)
This fund is a bequest of Archer E. Wheeler '95; its income is used for scholarship towards fees for undergraduates at the Institute.

Ray Hill White Memorial Fund (1956)
Income from this fund, established by Frances French White in memory of Ray Hill White '05, is used for scholarship assistance for poor and needy students.

Amasa J. Whiting Fund (1927)
This bequest of $2,000 from Mary W. C. Whiting was designated "to constitute a fund to be known as Amasa J. Whiting Fund . . . the income . . . to pay or help to pay tuition of deserving students whose means are limited. . . . Preference shall be given to students coming from the town of Hingham, Massachusetts."

Elizabeth Babcock Willmann Fund (1935)
This bequest from Elizabeth Babcock Willmann is "to help in paying the tuition of girl students taking the Chemistry Course."

John J. Wilson Scholarship Fund (1953)
The income from this fund, established by John J. Wilson '29, is used to assist a needy senior, first preference being one who has demonstrated interest and ability in the field of instrumentation for measurement and control and the intention of continuing his senior studies in this field.

Mary I. Wilson Scholarship Fund (1954)
Established by J. J. Wilson '29, this fund provides income to be used to assist worthy undergraduates in defraying their tuition obligations.

Morrill Wyman Fund (1915)
The income from this bequest of Morrill Wyman is "applied in aid of deserving and promising students, but without exclusion in regard to rank, upon the understanding that if in after life the person receiving aid shall find it possible, he shall reimburse the said fund for moneys so applied, but there shall be no legal obligation to make such reimbursement."

Conrad Henry Young Scholarship Fund (1957)
Established by the will of Abby W. Young in memory of Conrad Henry Young '96, the income of this fund is used for scholarships.

Undergraduate Prizes and Awards

To encourage and recognize high achievement by students at M.I.T., a number of prizes have been established by individuals and organizations. In general, these awards are made each year by the Office of the Dean of Students or by the departments or organizations concerned.

American Institute of Chemists Award (1957)
The American Institute of Chemists offers annually two medals, one to a student in chemistry and one to a student in chemical engineering. The medals are given to students who show outstanding professional promise.

Robert A. Boit Prizes (1921)
These annual prizes are made "to stimulate the interest in the best use of the English language" to undergraduates on the basis of essays written on topics approved by the Department of Humanities. The prizes are made possible by a bequest of $5,000 from Robert A. Boit.

Borden Freshman Prize (1956)
This $200 prize established by the Borden Company Foundation is awarded to the student who has achieved the highest average grade among all the members of his class for all college work during the freshman year.

Karl Taylor Compton Prizes (1951)
These prizes are awarded in recognition and encouragement of outstanding contributions in promoting high standards of performance and good citizenship within the Institute community. They are awarded from the income of a fund composed of gifts by members and friends of the Boston Stein Club.

Kendall Company Award
The Kendall Company makes available each year a prize of $100, to be awarded to the outstanding undergraduate member of the M.I.T. Chapter of Phi Lambda Upsilon, honorary chemical society. Selection is made on the basis of scholarship, character, and extra-curricular participation.

Ellen King Prize (1950)
This prize is a collection of books valued at approximately $50, awarded for the best essay written by a freshman upon any topic suitable for treatment in literary form. Papers submitted in a regular subject, as well as extracurricular compositions, will be eligible for the prize. Specific topics must be registered and approved at the Headquarters of the Department of Humanities.

Military Prizes
A number of individual prizes are awarded to selected outstanding cadets of each of the Military Departments on the basis of technical and professional proficiency.

M.I.T. Women's Association Award (1958)
This award of $100 is given to an outstanding woman student in the junior class.

Phi Lambda Upsilon Award in Freshman Chemistry
This award is given yearly to the outstanding student in freshman chemistry. Taken into consideration are academic achievement for the two semesters of freshman chemistry, over-all ability, interest, and promise.

Stratton Prizes (1930)
Yearly awards are presented to encourage skill in organized debating. They are made possible by the income of a fund established by the late President Samuel W. Stratton.

The following annual prizes are offered to students:

AERONAUTICS AND ASTRONAUTICS

Luis de Florez Awards (1960)
Rear Admiral Luis de Florez, distinguished engineer and alumnus of the Mechanical Engineering Department, Class of 1911, has endowed these awards in recognition of "outstanding ingenuity" in aeronautics and astronautics. The award is $500, with two honorable mentions of $100 each.

James Means Memorial Prize (1925)
A medal and monetary prize of $100 is offered annually to a senior for excellence in 16.71 FLIGHT VEHICLE ENGINEERING.

Henry Webb Salisbury Memorial Award (1941)
Established by the family and friends of Henry Webb Salisbury '33, this award consists of useful reference books presented to a student who has done outstanding work in the Department of Aeronautics and Astronautics.

ARCHITECTURE AND PLANNING

Alpha Rho Chi Medal (1932)
This medal is given each year to a graduating senior in the Department of Architecture who has shown an ability for leadership, performed willing service for his School and Department, and given promise of real professional merit through his attitude and personality.

Architecture Travel Fellowship (1960)
This award of $1,500, made by an anonymous donor, is given to a graduating student in architecture for travel in Europe.

Ernest A. Grunsfeld, Jr., Traveling Fellowship (1952)
This award of $1,200 is given to a fourth-year student in architecture for travel in Europe during the summer between his fourth and fifth years.

Rotch Prizes (1895)
Two prizes, the gift of Arthur Rotch, are awarded at the end of the fifth year to the regular and the special students in architecture having the best general records. The special student must have spent at least two years in residence to be eligible.

Skidmore, Owings and Merrill Travelling Fellowship (1950)
This award, a gift from the firm of Skidmore, Owings and Merrill, makes possible foreign travel for a student graduating in the Department of Architecture.

Student Medal of the American Institute of Architects (1914)
This medal is awarded on the recommendation of the Department to the member of the fifth-year class with the best record for the Course.

A number of smaller prizes are available for competitions in architectural design.

CHEMICAL ENGINEERING

Robert T. Haslam Cup (1959)
Established by Mr. and Mrs. Louis E. Seley in honor of Robert T. Haslam '11, this cup is awarded annually by the Department of Chemical Engineering to a senior who shows outstanding professional promise in chemical engineering.

Hunneman Prize (1927)
Established by William Cooper Hunneman in memory of his son, Roger DeFriez Hunneman '23, this award of $50 is made to the most meritorious senior who has shown outstanding originality in his work in the regular Course in Chemical Engineering.

CHEMISTRY

Merck and Co., Inc. Award
The Company offers annually one copy of *An Encyclopedia for Chemists and Members of Allied Professions* to a senior in chemistry who shows outstanding professional promise and is recommended by the Department.

CONSTRUCTION ENGINEERING

Tucker-Voss Award (1953)
Gift of the alumni and friends of the Course in Building Engineering and Construction, this prize is awarded annually to an undergraduate or a graduate student with high scholastic standing, leadership, and professional promise in the building field.

ELECTRICAL ENGINEERING

Blonder-Tongue Foundation Award (1959)
This annual prize of $250, awarded to a student in electrical engineering who has completed his junior year, is presented in recognition of high scholastic attainment and the demonstration of outstanding potential in the field of electronics. The recipient is determined during the latter half of his junior year by the faculty of the Department of Electrical Engineering. The award is a gift of the Blonder-Tongue Foundation, supported by Blonder-Tongue Laboratories Inc.

INDUSTRIAL MANAGEMENT

Industrial Management Association Award (1959)
This annual award of $100, established through the generosity of Samuel Berke '15, is made to the author of the best thesis submitted for the Bachelor of Science in Industrial Management.

MECHANICAL ENGINEERING

American Society of Tool and Manufacturing Engineers Prize (1945)
A prize of $100 is offered annually for the best graduation thesis on a subject related to the professional field of tool engineering. The prize is a gift of the Boston Section of the American Society of Tool and Manufacturing Engineers.

Luis de Florez Awards (1957)
Rear Admiral Luis de Florez, distinguished engineer and alumnus of the Mechanical Engineering Department, Class of 1911, has endowed these awards in recognition of "outstanding ingenuity" in mechanical engineering. The award is $500, with two honorable mentions of $100 each.

Silent Hoist and Crane Company Materials Handling Award (1950)
These annual prizes, totaling $200, are awarded for the best papers or theses submitted on subjects in the field of production, materials handling, or machine design related to materials handling equipment, on the basis of a competition held each year. The award is a gift of the Wunsch Foundation, Inc.

Machinery Award (1955)
This achievement award is presented to the outstanding student in machine design by *Machinery* magazine of New York City.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

American Bureau of Shipping Prize (1924)
This award of $100 is provided by the Bureau to the American citizen who attains the highest average in scholarship for the third and fourth years in either the Course in Naval Architecture and Marine Engineering or the Course in Shipping and Shipbuilding Management.

Financial Aid for Graduate Students

Financial aid is available in a number of forms for graduate students. A substantial number of scholarships and fellowships are awarded each year; in addition, there are many opportunities for academic staff appointments as part- or full-time teaching or research assistants. The requirements and application procedures for these financial aids are described in Section 3 of this Catalogue.

The Technology Loan Fund (described on a previous page) is also available to graduate students.

FELLOWSHIPS

The following fellowships will be available for the academic year 1961–62. The name in each case is that of the donor of funds which support the fellowship or of the person(s) memorialized by it.

VARIOUS FIELDS

Boeing Airplane Company
For a graduate student in engineering or science in a field relating to the aircraft industry; tuition plus $1,350.

William Sumner Bolles
For graduate work in any department; $1,200.

Coats and Clark, Inc.
Three fellowships, each for a graduate student in a field of textile technology whose thesis research is in that division; tuition plus $900.

Electronics Industries
For graduate work in electronics; tuition plus $1,800 single, $2,400 married, advanced fellowships up to $3,000. Sponsored by the Federal Telecommunication Laboratories, Hughes Aircraft Company, Radio Corporation of America, and Sperry Gyroscope Company.

Owens-Corning Fiberglas Corporation
For a graduate student in the field of materials engineering; tuition plus $2,500.

Solar Energy
Four fellowships for graduate students, candidates for the doctorate in chemistry, physics, or engineering or candidates for Master in Architecture, for study in a field which may lead to improved use of solar energy; tuition plus $1,400 single, $2,100 married; for two terms but renewable.

Alfred P. Sloan
For U.S. male first-year graduate students in engineering who intend to enter teaching profession; tuition plus $1,800 single, $2,400 married.

Standard Oil Foundation
For a full-time student who has completed at least one year of graduate study in chemistry or chemical engineering; tuition plus $2,000.

Gerard Swope
For students of exceptional ability and promise, as a mark of highest distinction.

Wasserman
For a graduate student in engineering, architecture, or industrial management, to support study in the general area of plastics; tuition plus $2,000.

Whitney
For an entering graduate student from other than M.I.T., in any department; tuition plus $1,800.

AERONAUTICS AND ASTRONAUTICS

AC Spark Plug
For a graduate student in instrumentation; tuition plus $2,100.

Aviation Week
For a male U.S. citizen enrolled for an advanced degree, renewable as long as satisfactory academic rating is maintained; tuition plus $1,600.

Convair
For study in the general field of automatic controls and servomechanisms; tuition plus $2,000.

Douglas Aircraft Company
For a highly recommended graduate student; tuition plus $750.

Richard C. Du Pont
Memorial fellowship in aeronautics and astronautics, for a graduate student in any year of his work toward an advanced degree; tuition plus $1,400 single, $2,000 married.

Lester D. Gardner
For a graduate student; tuition plus $1,400.

Goodyear Tire and Rubber Company and Goodyear Aircraft Corporation
For an American citizen graduate student; tuition plus $1,500.

Lockheed Leadership Fund
For a graduate student in the field of aerodynamics; tuition plus $1,400.

H. N. Slater
For full-time study in flight transportation; tuition plus $2,500.

Sperry Gyroscope Company
Two fellowships, each for a graduate student in aeronautics and astronautics; tuition plus $2,000.

ARCHITECTURE

W. Danforth Compton Memorial
For graduate students of exceptional ability. Awards up to tuition plus $1,000.

Grunsfeld Fund
For a distinguished advanced French student of the Ecole des Beaux Arts, for a year's study at M.I.T. and travel in the United States, to be selected from nominations presented to M.I.T. by the Ecole des Beaux Arts; tuition plus $1,500.

Grunsfeld Fund
Tuition for one term.

BIOCHEMISTRY

Karl Taylor Compton Fellowships of the Nutrition Foundation
Fellowships for graduate work in the field of biochemistry; each tuition plus $2,000.

General Foods Corporation
For an entering graduate student in biochemistry, whose research will be in the area of enzymology; tuition plus $1,400 renewable for each of two succeeding years.

Upjohn Company
For a graduate student in biochemistry; tuition plus $1,800.

CHEMICAL ENGINEERING

American Cyanamid Company
For several graduate students in chemical engineering for one semester each in the School of Chemical Engineering Practice; tuition plus $500.

American Oil Company
Two fellowships for students who attend either the School of Chemical Engineering Practice or the Engineering Practice School at Oak Ridge for one term; tuition plus $700.

R. M. Carpenter
Tuition plus $1,400.

Eastman Kodak Company
For a U.S. citizen in final year of Sc.D. research; tuition plus $1,400 single, $2,100 married with dependent children.

Eastman Kodak Company
For two M.S. students (preferably U.S. citizens) to attend the School of Chemical Engineering Practice; tuition for one term.

Humble Oil and Refining Company
For several graduate students in chemical engineering for one semester each in the School of Chemical Engineering Practice; tuition plus $500.

Humble Oil and Refining Company
For a student enrolled for S.M. or a doctorate; tuition plus $1,800.

Arthur D. Little
Memorial fellowship for a candidate for a doctorate, for two regular terms and one summer term; tuition plus $2,100.

Procter and Gamble Company
For a student in his final year of graduate study; tuition plus $1,800 single, $2,100 married.

Scientific Design Company
For a graduate student in chemical engineering; tuition plus $1,500 single, $2,100 married.

Union Carbide Chemicals Company
For a graduate student in chemical engineering; tuition plus $1,500 single or $2,100 married, for normal academic year or (at M.I.T.'s discretion) for calendar year.

Union Carbide Chemicals Company
For a student who attends either the School of Chemical Engineering Practice or the Engineering Practice School at Oak Ridge, for one, two, or three terms; tuition plus $1,400 single, $2,100 married, per twelve-month period.

CHEMISTRY

Allied Chemical Corporation
For an American or Canadian citizen in the final year of graduate study; tuition plus $2,000 single, $2,500 married.

American Cyanamid Company
For a graduate student during his final academic year of residence in work toward the doctorate; tuition plus $1,800.

Consumers Union
For a graduate student in chemistry in the field of physical chemistry of surfaces; tuition plus $1,000.

Eastman Kodak Company
For a graduate student in chemistry; tuition plus $2,000.

Esso Education Foundation
For a graduate student in chemistry who has completed at least one year of graduate work; tuition plus $2,400 single or married without children; tuition plus $3,000 married with one or more children. Fellowship tenable for twelve months.

General Electric Company
For a graduate student in chemistry; tuition plus $1,750 single, $2,100 married with no dependent children, $2,500 married with one or more dependent children; such status to be as of September 30, 1961.

Arthur D. Little
Memorial fellowship for a candidate for a doctorate in chemistry; tuition plus $1,400.

Minnesota Mining and Manufacturing Company
For a graduate student in chemistry; tuition plus $2,000.

Forris Jewett Moore Memorial
For graduate study at M.I.T. or elsewhere, preference being given to a student in organic chemistry; tuition plus $1,400.

James Flack Norris Memorial
For a candidate for a doctorate, $2,500.

Procter and Gamble
Tuition plus $1,800 single; tuition plus $2,100 married.

Standard Oil of Ohio
For a graduate student in the field of inorganic chemistry; tuition plus $1,800.

Sun Oil Company
For a graduate student and American citizen in his final year of study for the doctorate; tuition plus $1,800 single or married without children; tuition plus $2,300 married with children.

Union Carbide Chemicals Company
For a graduate student in his final year of predoctoral study; tuition plus $1,800 single, $2,100 married.

United States Rubber Company Foundation
For a male candidate for a doctorate; tuition plus $1,800 single or married without children under school age; $2,100 married with children.

CITY PLANNING

F. W. Chandler
Awarded in alternate years upon recommendation of the Head of the Department to a candidate for the M.C.P.; $1,000.

CIVIL ENGINEERING

McClintock Endowment
For a graduate student in civil engineering; tuition plus $1,300.

ECONOMICS

Economic Development
For a graduate student in the Department of Economics; tuition plus $1,500.

Goodyear Tire and Rubber Company
For a graduate student in the field of industrial economics or industrial relations; tuition plus $2,000.

Clarence J. Hicks Memorial
For a graduate of not more than five years (exclusive of military service) since his baccalaureate from a college or university in the U.S. or Canada, who is a candidate for a doctorate at M.I.T. in the field of industrial relations; tuition plus $750.

Industrial Economics and Industrial Relations
For candidates for the doctorate in these fields; several, tuition plus $1,000.

Rand Corporation
For a graduate student in the field of mathematical economics; tuition plus $1,750.

Westinghouse Fellowship in Industrial Relations
For a graduate student in this field; tuition plus $1,000.

ELECTRICAL ENGINEERING

Bendix Aviation Corporation
For a U.S. citizen well advanced in a doctoral program whose field of study is of interest to the donor; tuition plus $1,800 single, $2,400 married.

General Dynamics Corporation
For a graduate student in the field of electronics; tuition plus $1,800 single, $2,500 married.

International Business Machines Corporation
For a graduate student in electronics, communications, and information handling; tuition plus $1,800 single or married with no children, $2,500 married with children.

Melpar, Incorporated
For a graduate student in electronics and communications; tuition plus $1,800 single, $2,400 married.

Minneapolis-Honeywell
For graduate work in feedback control; tuition plus $1,800.

Owens-Corning Fiberglas Corporation
For a graduate student in acoustics; tuition plus $1,800 single, $2,400 married.

Schlumberger Foundation
For a graduate student in electrical engineering; tuition plus $1,800.

Xerox Corporation
For a predoctoral or postdoctoral student who will carry out an investigation of solid state physics as a member of the Laboratory for Insulation Research; tuition plus $2,500. Fellowship tenable for twelve months.

GEOLOGY AND GEOPHYSICS

Gulf Research and Development Company
For a graduate student in geophysics, preferably but not necessarily to a doctoral candidate beyond his first year of graduate study, for two regular terms; tuition plus $2,000.

Standard Oil Company of California
For a graduate student in the field of earth science; tuition plus $1,500.

INDUSTRIAL MANAGEMENT

Eastman Kodak Company
For a graduate student in his terminal year of study for the doctoral degree; tuition plus $2,500 single or $3,000 married with dependent children, for a twelve-month period. For a nine-month period, tuition plus $2,000 or $2,500, respectively.

Lord Heyworth
For a full-time S.M. candidate in industrial management; tuition plus $1,000.

Ohio Oil Company Foundation
For a graduate student in industrial management; tuition plus $1,500 single, $2,000 married.

School of Industrial Management
For advanced study and research in industrial management, for college graduates whose major studies have been in science, engineering, and engineering administration. A number of fellowships; tuition plus up to $1,400 single, up to $2,100 married. Awards may be continued for second year of study if performance justifies.

Sloan
For training in executive development, for industrial executives of some experience who are nominated by their employers, a twelve months' program with grants.

United States Steel Foundation
For a U.S. citizen graduate student in the general area of industrial organization and management; tuition plus $1,500 single, $2,100 married.

MATHEMATICS

Mathematics
For graduate students who are studying in the Department of Mathematics for careers in research or teaching in the various fields; tuition plus $1,300.

MECHANICAL ENGINEERING

Cummins Engine Foundation
For a U.S. citizen and full-time student preferably working toward Ph.D. (or Sc.D.); tuition plus $2,400 single or married with no children, tuition plus $3,000 married with children.

Foundation for Instrumentation Education and Research (F.I.E.R.)
For study in the area of instrumentation and automatic control; tuition plus $700.

Lasalle Steel Foundation
For a graduate student working either toward S.M. or Sc.D. in mechanical engineering, whose major field of interest including thesis is in metal cutting; tuition plus $1,400 single, $2,000 married.

Procter and Gamble
For a graduate student in mechanical engineering; tuition plus $1,400 single, up to $2,100 married.

Shell
For a graduate student, candidate for the S.M. or the doctorate, preference to be given to doctoral candidate in last year of work; tuition plus $1,800 single, $2,100 married with one or more children; renewable.

Visking
For a graduate student in the final year of a doctoral program; tuition plus $1,800 single, $2,100 married.

METALLURGY

Allegheny-Ludlum
Two fellowships for graduate students whose thesis research is on topics of interest to the alloy steel industry; tuition plus $1,800–$2,400.

American Brake Shoe Company
For a Master's degree candidate in foundry engineering; tuition plus $1,400.

General Electric
For a graduate student in metallurgy; tuition plus $1,750 single, $2,100 married with no dependent children, $2,500 married with one or more dependent children; such status to be as of September 30, 1961.

General Electric
For a graduate student in the field of materials science and engineering; tuition plus $1,750 single, $2,100 married with no dependent children, $2,500 married with one or more dependent children, such status to be as of September 30, 1961.

International Nickel Company
For a graduate student in the field of materials science and engineering; tuition plus $2,100 per calendar year.

Kennecott Copper Corporation
For a graduate student in metallurgy; tuition plus $2,500.

National Steel Corporation
For a graduate student in metallurgy whose research is in the general field of the plastic behavior of steel; tuition plus $2,100.

National Steel Corporation
For fundamental studies in corrosion; tuition plus $2,100.

Steelmaking
Tuition plus $1,400.

Union Carbide Chemicals Company
For a graduate student in the general field of metallurgy; tuition plus $1,500 single, $2,100 married, for two regular terms.

Union Carbide Chemicals Company
For a graduate student in the field of mineral engineering; tuition plus $1,500 single, $2,100 married, for two regular terms.

Universal-Cyclops Steel Corporation
For a candidate working on tool steel; tuition plus $1,600.

METEOROLOGY

Atmospheric Sciences and Oceanography
For graduate students in any year of work for a doctorate; tuition plus $3,000.

NUCLEAR ENGINEERING

General Dynamics Corporation
For a graduate student in nuclear engineering; tuition plus $1,800 single, $2,500 married.

NUTRITION, FOOD SCIENCE AND TECHNOLOGY

American Chicle Company
Tuition plus $1,600.

Campbell Soup Company
For a graduate student in nutrition, food science and technology; tuition plus $2,100 single, $2,400 married.

Procter and Gamble
For a graduate student in nutrition, food science and technology; tuition plus $1,600–$2,200.

Roche Anniversary Foundation
Tuition plus $1,600.

PHYSICS

General Electric
For a graduate student in physics; tuition plus $1,750 single, $2,100 married with no dependent children, $2,500 married with one or more dependent children; such status as of September 30, 1961.

Eastman Kodak Company
For a U.S. citizen in his final year of Ph.D. research; tuition plus $1,400 single, $2,100 married with dependent children.

International Business Machines Corporation
For a graduate student in physics; tuition plus $1,800 single or married without children; $2,500 married with one or more children.

Kennecott Copper Corporation
For a graduate student in solid state physics; $1,000 towards tuition plus $2,500 single; tuition plus $2,500 married.

Shell
For a candidate for the S.M. or the doctorate, preference to be given to doctoral candidate in last year of work; tuition plus $1,800 single, $2,100 married with one or more children.

SCHOLARSHIPS

UNRESTRICTED FUNDS

Graduate Scholarships
Scholarships totaling $120,000 are available for 1961–62.

REGIONAL AWARDS

Imperial College of Science and Technology, London
Tuition.

M.I.T. Clubs of Mexico
For a graduate student nominated by the alumni of the M.I.T. Clubs of Mexico City and Monterrey; tuition.

Vermont Scholarship
Open to a native of Vermont or a graduate of Middlebury College or Norwich University. Undergraduate applications have preference; tuition.

Prizes and Awards for Graduate Students

The following awards have been established to recognize outstanding teaching and research by graduate students:

The Brooks Prize in Industrial Management
The E. P. Brooks Master's Thesis Prize is awarded each year for the thesis judged to be the best submitted for the Master of Science in Industrial Management. Recognition takes the form of an award of $100 and publication of the thesis by the School. Nominations may be made by the chairman of any Master's Thesis Committee to the School of Industrial Management's Prize Committee.

The Goodwin Medal[1]
The Goodwin Medal together with a cash prize may be awarded in any year (but not necessarily in every year) to a graduate student who is also a member of the academic staff of the Massachusetts Institute of Technology, in recognition of conspicuously effective teaching. Candidates for this award are nominated through departmental channels or by the Student-Faculty Committee to the Dean of the Graduate School.

The Goodwin Premium[1]
In any year in which there is no qualified candidate for the Medal, a cash award not to exceed $500 may be granted to any graduate student in recognition of originality, ingenuity, thoroughness, and a scholarly written presentation of research embodied in a thesis of conspicuously unusual merit. As in the case of the Medal, nominations but not applications are receivable by the Dean of the Graduate School.

[1] Established in memory of Dr. Harry Manley Goodwin, the first Dean of the Graduate School, through a fund given by Mary B. and Richard H. Goodwin.

TECHNOLOGY LOAN FUND

Since its establishment in 1930, the Technology Loan Fund has provided more than $6,000,000 in loans to over 6,700 M.I.T. students.

In general, loans are made by the Student Financial Aid Committee to (a) students entering the Institute directly from secondary schools who are well recommended, (b) students who have completed at least one term of residence with a good academic record.

The maximum amount loaned to an individual in a single year may not exceed the tuition fee, and the maximum total loans granted to an applicant may not exceed $6,000 for the total period of enrollment.

Application forms are available from the Student Aid Center. To receive favorable consideration an applicant must:

1. Be endorsed as to character and personality by: (a) an alumnus of the Institute from the community in which he has resided or by some other citizen of standing in that community; (b) the principal or head master of the high school or preparatory school or the president or dean of the college or university he has previously attended; and (c) his Registration Officer or the Head of his Course.

2. Have passed, with a standing satisfactory to the Committee, the physical examination required of all Institute students.

3. Submit a statement of his financial needs and such other information as the Committee may deem necessary, on the application form supplied by the Committee, such application to have the approval of his parent or guardian.

4. Be prepared to furnish as collateral such life insurance as may be required by the Committee.

The recipient of a loan signs promissory notes in $150 units up to the amount of his loan. Each such loan carries interest at one per cent per annum during the period of enrollment and at two per cent per annum beginning six months after the termination of enrollment. During enrollment interest is paid semiannually; annual payments of $300 on principal start six months after graduation or termination of enrollment. Principal payments may be made on either a monthly, quarterly, semi-annual, or annual basis; they may also be anticipated.

After he leaves the Institute, the recipient of a loan is required to advise the Committee annually, or at more frequent intervals, of his whereabouts, the character of the work in which he is engaged, the remuneration he is receiving, and his plans for the repayment of his obligations to this Fund.

OTHER LOAN FUNDS

The following funds have been established for special purposes at the Institute. In general, these loan funds are administered under terms similar to those governing the Technology Loan Fund, and inquiries should be made to the Director of Student Aid.

Boston Stein Club Freshman Loan Fund (1953)
Established by the M.I.T. Boston Stein Club, this fund is designed to assist needy students resident in the Greater Boston area. It is open only to first-year students who show good promise, and, in general, grants are for less than full tuition. Recipients are required to sign notes to repay amounts granted, without interest, after graduation.

Denison K. Bullens Fund (1958)
Gift of D. K. Bullens '09, the income of this fund is used as a loan to assist needy and worthy undergraduates, with first preference to a student in metallurgy.

Ethel I. Fryer Scholarship Loan Fund (1951)
This fund was a gift of H. Fryer '11 to establish a loan scholarship for deserving students from the states of Washington, Oregon, and California. Grants are limited to $600 per student and are repayable within five years of graduation.

Nathan R. George Loan Fund (1943)
This bequest of $29,000 from Professor Nathan R. George of the Department of Mathematics is "to be loaned to undergraduates of M.I.T. who are either citizens or who intend to become citizens" and who are members of the third- or fourth-year classes.

John A. Grimmons Fund (1930)
In memory of John A. Grimmons '21 through a deed of trust executed by the late C. Lillian Moore, the Institute received a sum of money to be "used in making loans to undergraduates who are preparing to make electrical engineering their life work; such loans to be known as given from the John A. Grimmons Perpetual Loan Scholarship; such loans are not to exceed $600 to any one student in any one year and are to be made on condition that the loans shall bear interest at five per cent and shall be repaid within ten years, and that repaid loans shall be treated as income to revert into the Perpetual Loan Fund and to be reloaned from time to time; such loans are to be protected by life insurance. . . . Loans are to be awarded to male, white, native born citizens of the United States, who are loyal to the State and Nation, are of sound physical body, and show steadiness of purpose and zeal in educational acquirements."

Rebecca R. Joslin Fund (1924–36)
This fund is open to undergraduate and graduate students in chemical engineering and is restricted to students who are residents of Massachusetts and who abstain from using tobacco in any form.

Lamson-Virgin Loan Fund (1946)
This bequest of $5,000 from Elizabeth H. Lamson is used in aiding a worthy student of excellent character who "must have shown not only respect for his parents but also proper consideration for the rights of others." Students thus aided shall repay if and when they find themselves able to do so.

George J. Mead Fund (1951)
This bequest of George J. Mead '16 is for loans to students in aeronautics and astronautics and mechanical engineering.

M. H. Rogers Fund (1945)
This bequest of Minnie Hempel Rogers '90 is for loans to worthy students.

Technology Matrons Student Aid Fund (1960)
This gift of the Technology Matrons is used to assist needy and worthy students with loans.

Frank P. Wakefield Fund (1955)
One-fourth of the income of this fund is available for loans to needy and worthy students majoring in chemistry, chemical engineering, and biology.

APPENDIX B: STUDENT HOUSING

The student Houses of the Institute are maintained to provide an atmosphere conducive to suitable study and living habits and an opportunity to participate in those social and extracurricular activities which properly supplement scholastic work. Masters or Faculty Residents occupy quarters in each of the residential centers. Chosen for their understanding of students and student questions, these men welcome informal friendly discussions with their fellow residents.

The Institute believes that it is to the great advantage of all students who do not live at home to live in Institute Houses or in fraternities. As far as accommodations allow, such residence is required for all freshmen unless other special arrangements are approved by the Dean of Residence. Upperclassmen are free to make whatever living arrangements they choose.

Determination and maintenance of living conditions within the Houses is the responsibility of the Dean of Residence. The student Dormitory Council organizes and supervises student activities, athletic and social, and cooperates with recognized undergraduate activities at the Institute. A House tax included in the rental is turned over to the Dormitory Council to support social and athletic activities. It is expected that all students will comply with those rules and regulations currently in effect. The Institute reserves the right to terminate the privilege of House residence for any student found violating either House regulations or acceptable standards of community behavior.

THE UNDERGRADUATE HOUSES FOR MEN

The Everett Moore Baker House (West Campus), located on the river front at 362 Memorial Drive, Cambridge, west of Massachusetts Avenue, accommodates some 350 students in single, double, or triple rooms. The House has its own dining facilities, where residents are expected to take commons meals.

The Alfred Edgar Burton House (West Campus), also on the river front at 410–420 Memorial Drive, Cambridge, west of Baker House, accommodates about 570 students. It consists of five bays, two of which are known as Conner Hall. There are some single and double rooms, but most of the accommodations are suites of rooms designed for larger groups. Burton House has its own dining facilities, where residents are expected to take commons meals.

The Senior House (East Campus) — Ware, Atkinson, Runkle, Holman, Nichols, and Crafts — on Memorial Drive, east of Walker Memorial and adjacent to the President's House, accommodates 194 students.

The Alumni Houses (East Campus) — Munroe, Hayden, Wood, Goodale, Bemis, and Walcott — near Walker Memorial, have accommodations for 417 men.

Dining facilities for residents of the East Campus Houses are in the Walker Memorial Building. They include a large cafeteria, where both commons meals and à la carte service are provided, and a modern social room and soda bar, where light refreshments are served. The latter, known as Pritchett Lounge, is open during evening hours and has a dance floor and other facilities for entertainment.

Furnishings and Maintenance

Provisions for furnishings and maintenance must necessarily reflect economic conditions, and are subject to review and change at the end of each academic year. All single rooms in the undergraduate Houses have a bed or studio couch, mattress, pillow, mirror, chiffonier or wardrobe, desk and chair, study chair, bookcase, wastebasket, light bulbs, and extra electrical outlets. Double and triple suites are furnished in a manner similar to the single rooms. Each occupant is required to complete an equipment inventory acknowledgment at the opening of the fall term, indicating the condition of the room and the furnishings. Bed linen and blankets are not furnished. Students may bring their own bedding with them or may obtain it through a rental service available at the desk of each House. For the current rent of $20, payable at the beginning of the fall term and refundable pro rata if the student does not complete the year, the service supplies blankets for a year and two clean sheets and one clean pillow case each week. Students in all Houses provide their own towels and soap and clean their own rooms, with occasional assistance from the porter staff.

For maintenance and safety, rooms are inspected regularly during normal working hours by responsible Institute personnel. Every effort is made for the physical safety of residents of the Houses, with proper fire alarm systems, fire extinguishers, and other equipment. Tampering with the protective systems or with the telephone system is a danger and a nuisance to others and is regarded as a serious offense, meriting the immediate and permanent exclusion of the offender from the Houses.

The Institute does not carry fire insurance covering property of residents of the Houses, who therefore may wish to provide their own by direct contract or by a rider on a family domestic policy.

Rents

Rooms in the Institute Houses are assigned on the basis of application forms distributed to residents each spring and to entering freshmen and transfer students with their notices of admission. Rooms are engaged for the full academic year; and with exceptions as approved by the Dean of Residence, a student who is assigned quarters on application is responsible for the rent thereof for the academic year of assignment.

Rates range from $150 to $235 per person per term and are subject to review and revision each January for the following academic year. Rental assignments are automatically canceled and a proportionate refund is allowed to any student who withdraws from the Institute during the first five weeks of the term. After the fifth week, refunds are made only in special circumstances approved by the Dean of Residence.

Rent for the full term is payable with tuition to W. A. Hokanson, Bursar, except when prior arrangements are made for deferred or periodic payments. Details of assignment, occupancy, and specific rentals — with other pertinent details — are published annually in a pamphlet entitled "Residence at M.I.T.," available from the Dean of Residence, Room 7–104.

Basic Regulations

In applying for a room in the Houses, a student is understood to agree to abide by the following basic regulations:

1. Only one room application form per student may be filed. Duplicate applications will not be considered.

2. Upperclassmen who are assigned rooms in the Houses in the spring will receive a card which must be signed and returned by August 1 in order to confirm acceptance of a room assignment. Students from whom no card is received will lose their assignment and be transferred to the bottom of the waiting list. Under special conditions approved by the Dean of Residence, students may be relieved of the responsibility for confirmed assignments up to, but not including, Registration Day in September.

3. Room changes within the dormitories will be made only in special circumstances and only with the approval of the Dean of Residence. Changes requested during the first three weeks of any term will not be effected until the end of the three-week period. Vacancies occurring during the first three weeks of any term will be filled directly from the waiting list, if any. At the end of the three-week period, priority in moves will be given residents as of Registration Day over men assigned rooms after Registration Day.

4. Students engaging rooms in the Houses will be considered responsible for the rent thereof for the full academic year except if they (1) leave the Institute, (2) move to a fraternity as indicated below, (3) secure a new occupant not in residence to take over the room, (4) present special circumstances to the satisfaction of the Dean of Residence.

5. Students living in the undergraduate Houses who desire to move to recognized fraternities during the first two weeks of either the first or second term will be refunded the rental fee less a pro rata charge for occupancy.

6. The Institute reserves the right to move students within the Houses at its discretion, in order to consolidate vacancies, to meet other demands upon dormitory facilities, etc. In these circumstances students will be allowed to leave the Houses, instead of moving, provided they have the approval of the Dean of Residence.

7. Students who do move from the Houses for any reason will be responsible for room rent until they have signed out at the office of the Dean of Residence, Room 7-104.

8. As a general rule, students may not occupy doubles as singles, triples as doubles, etc. If extra rooms are available, students may so occupy rooms at the Institute's convenience or protect the privilege in any given term by payment of $50.00 each.

9. For reasons of safety and sanitation, no cooking equipment may be used in the rooms of the Houses. Hot plates, electric frying pans, percolators, and other similar equipment therefore may not be kept in the rooms. If brought to Cambridge, they must be stored with the superintendent of the House. Exceptions to this regulation will be made only on approval of the Dean of Residence for special reasons such as medical necessity.

10. Refrigerators are allowed in students' rooms but must be licensed at a fee of $5.00 per term to cover costs. Refrigerators are subject to inspection for reasons of safety and sanitation.

11. Damage to Institute property in the Houses is the responsibility of the residents. Each student is held accountable for any damages in his own room. Damage to the entire dormitory or any part thereof will be charged to the residents of the dormitory. Student government may determine individual assessments.

12. All students electing to live in Burton House and Baker House are required to register for commons meals. Students who for medical or other reasons require special diets should apply for residence in Senior House or the East Campus Houses.

13. Regulation of extracurricular activities in the Houses is among the responsibilities of student government in the Houses, in consultation with the Dean of Residence. The faculty and administration expect all students to abide by the regulations of student government.

14. Administration of parietal rules covering visiting hours for women guests is the responsibility of the Dean of Residence, in consultation with the appropriate student governing groups.

15. The manufacture, storage, or use of dangerous chemicals, explosives, or ammunition in the Houses is forbidden. Detonation of firecrackers or other explosives and the throwing of missiles of any kind from or within the Houses are forbidden. Tampering with fire-protection equipment in the Houses is forbidden. Violation of these regulations, or the committing of any other acts interfering with proper study conditions in the Houses or with the rights of the community at large, renders the violator subject to disciplinary action.

16. Firearms, air rifles, and air pistols possessed by residents of the Houses must be registered with the Superintendent of the House and the Chairman of the House Executive Committee. Ammunition must be stored with the Superintendent of the House. Residents are reminded that firearms in their possession should also be licensed in accordance with the laws of the Commonwealth of Massachusetts.

Key Deposits

A deposit of $1 is required for a room key, subject to refund in full upon return of the key.

Parking and Automobile Regulations

Because of the acute shortage of on-campus parking space, the Institute cannot provide parking facilities for use of resident students. A limited number of spaces are provided, with the approval of the Dean of Residence, for residents with physical handicaps demanding use of an automobile.

Operators of motor vehicles should consult the Massachusetts Registry of Motor Vehicles regarding regulations and insurance on out-of-state motor vehicles. The registration and operating licenses of certain states are not honored in Massachusetts after thirty days.

RESIDENCES FOR WOMEN STUDENTS

The Women's Dormitory, at 120 Bay State Road, Boston, accommodates 17 students. The current rate for room and board is $450 per person per term. Application forms and further information may be obtained from the Dean of Residence, Room 7-104.

Apartment dormitory accommodations are available for 33 upperclass and graduate women students in Bexley Hall, 52 Massachusetts Avenue, Cambridge, opposite the main Institute buildings. Apartments are

for two or three occupants and are fully furnished and equipped except for blankets, linens, and draperies. The building — one unit of the Bexley Hall apartment house — has a separate entrance, is protected by a fire-sprinkler system on main and service staircases, contains a self-service machine laundry, and provides a basement storage space for each apartment. Rent, including gas and electricity, is $220 per person per term. Application forms and further information may be obtained from the Dean of Residence.

THE GRADUATE HOUSE

The Graduate House, at 305 Memorial Drive, is a center for the social life of the graduate student community. Its rooms are reserved exclusively for men graduate students.

Application forms for rooms are distributed to residents each spring and to entering graduate students with their notifications of admission. They should be filed with the Superintendent of the Graduate House. In general, accommodations are insufficient to meet the demand at the beginning of each year, and there is usually a waiting list. Priority is granted to graduate students already living in the House whose applications are filed in accordance with instructions distributed each spring.

Notices of assignment will be forwarded to applicants as promptly as possible. Acceptances must be returned as requested; otherwise, the rooms may be reassigned. The assignment of rooms is in order of application; the right is reserved to reject any applicant for sufficient reason.

Rents in the Graduate House range from $140 to $215 per person per term. Rent for the full term is payable with tuition to W. A. Hokanson, Bursar, except when prior arrangements are made for deferred or periodic payments.

Rooms are engaged for the full academic year. Reservations are automatically canceled and proportionate refunds are made to students who cancel their registration during the first five weeks of the term. After the fifth week no refund is made except in special circumstances approved by the Dean of Residence.

Equipment and service in the Graduate House, basic regulations, key deposits, and parking and automobile regulations are the same as those given above for the undergraduate Houses.

DINING SERVICES

Commons meals are served Monday through Friday in Institute dining rooms in Walker Memorial, Burton House, and Baker House, except during stated vacation periods. Commons meals are required for Burton House and Baker House residents; residents of the other undergraduate Houses and of the Graduate House may elect the commons plan in Walker. A la carte service is available in Walker Monday through Friday and in the Graduate House dining room seven days a week.

Election of the commons plan is for the full term in which it is made. The contract is automatically canceled and a proportionate refund is made upon withdrawal of a student from the Institute during the first five weeks of the term. After the fifth week refunds are made, at the rate of $6 per week or more, in special circumstances approved by the Dean of Residence.

The price of commons meals is reviewed each January for the following academic year. For the academic year 1961–62, the rate will be $12.50 per week: $212.50 for the fall term and $200 for the spring term. All fees for commons meals are payable, with rent and tuition, to the Bursar at the beginning of each term. Students may arrange before the term begins to make deferred or periodic payments.

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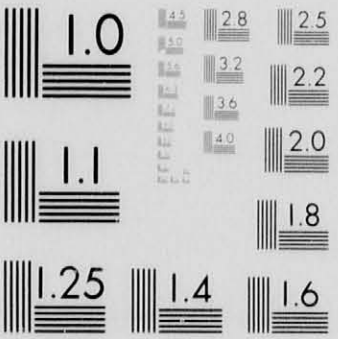
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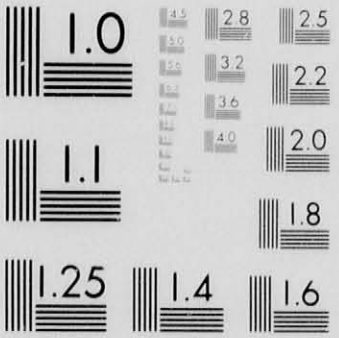
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