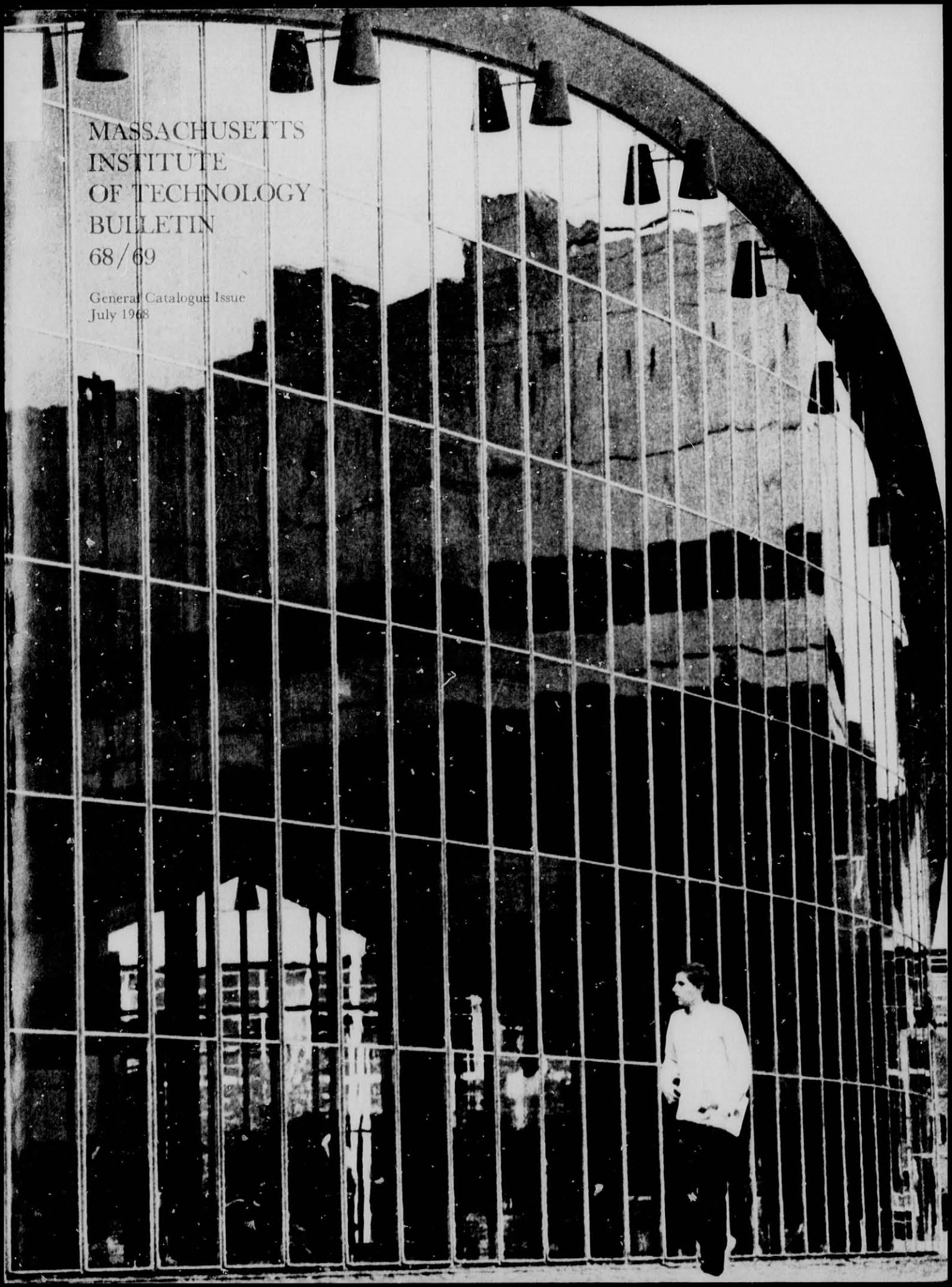
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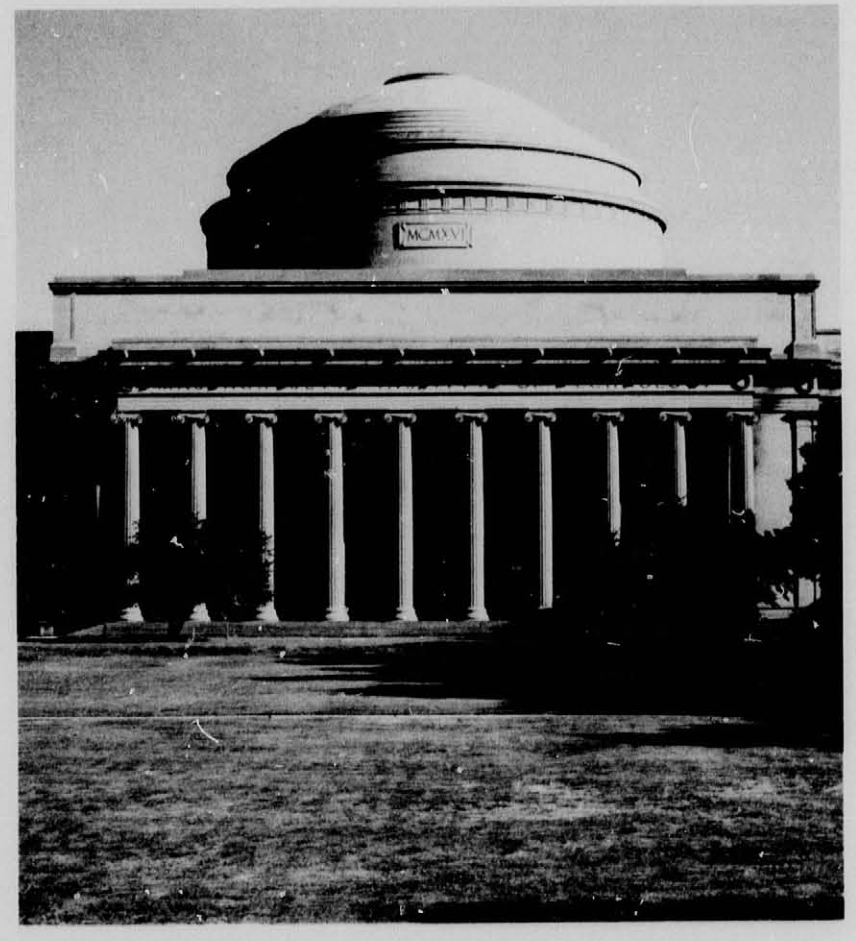
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ACADEMIC CALENDAR

1968

SEPTEMBER 18	FRESHMAN WEEKEND BEGINS
SEPTEMBER 23	FIRST TERM REGISTRATION DAY
SEPTEMBER 24	FIRST TERM CLASSES BEGIN
SEPTEMBER 25	ALTERNATE FIRST TERM REGISTRATION DAY
OCTOBER 12	COLUMBUS DAY (*holiday*)
NOVEMBER 11	VETERANS' DAY (*holiday*)
NOVEMBER 28 *through* DECEMBER 1	THANKSGIVING VACATION
DECEMBER 21 *through* JANUARY 5	CHRISTMAS VACATION





1969

JANUARY 22	LAST EXERCISES OF THE FIRST TERM
JANUARY 23 *through* JANUARY 25	READING PERIOD
JANUARY 27 *through* JANUARY 31	EXAMINATION PERIOD
FEBRUARY 10	SECOND TERM REGISTRATION DAY
FEBRUARY 11	SECOND TERM CLASSES BEGIN
FEBRUARY 17	OBSERVANCE OF WASHINGTON'S BIRTHDAY (*holiday*)
MARCH 31 *through* APRIL 6	SPRING VACATION
APRIL 21	OBSERVANCE OF PATRIOTS' DAY (*holiday*)
MAY 26	OBSERVANCE OF MEMORIAL DAY (*holiday*)
MAY 28	LAST EXERCISES OF THE SECOND TERM
MAY 29 *through* MAY 31	READING PERIOD
JUNE 2 *through* JUNE 6	EXAMINATION PERIOD
JUNE 13	COMMENCEMENT DAY
JUNE 23	SUMMER SESSION 1969 BEGINS
SEPTEMBER 22	FIRST TERM 1969 REGISTRATION DAY

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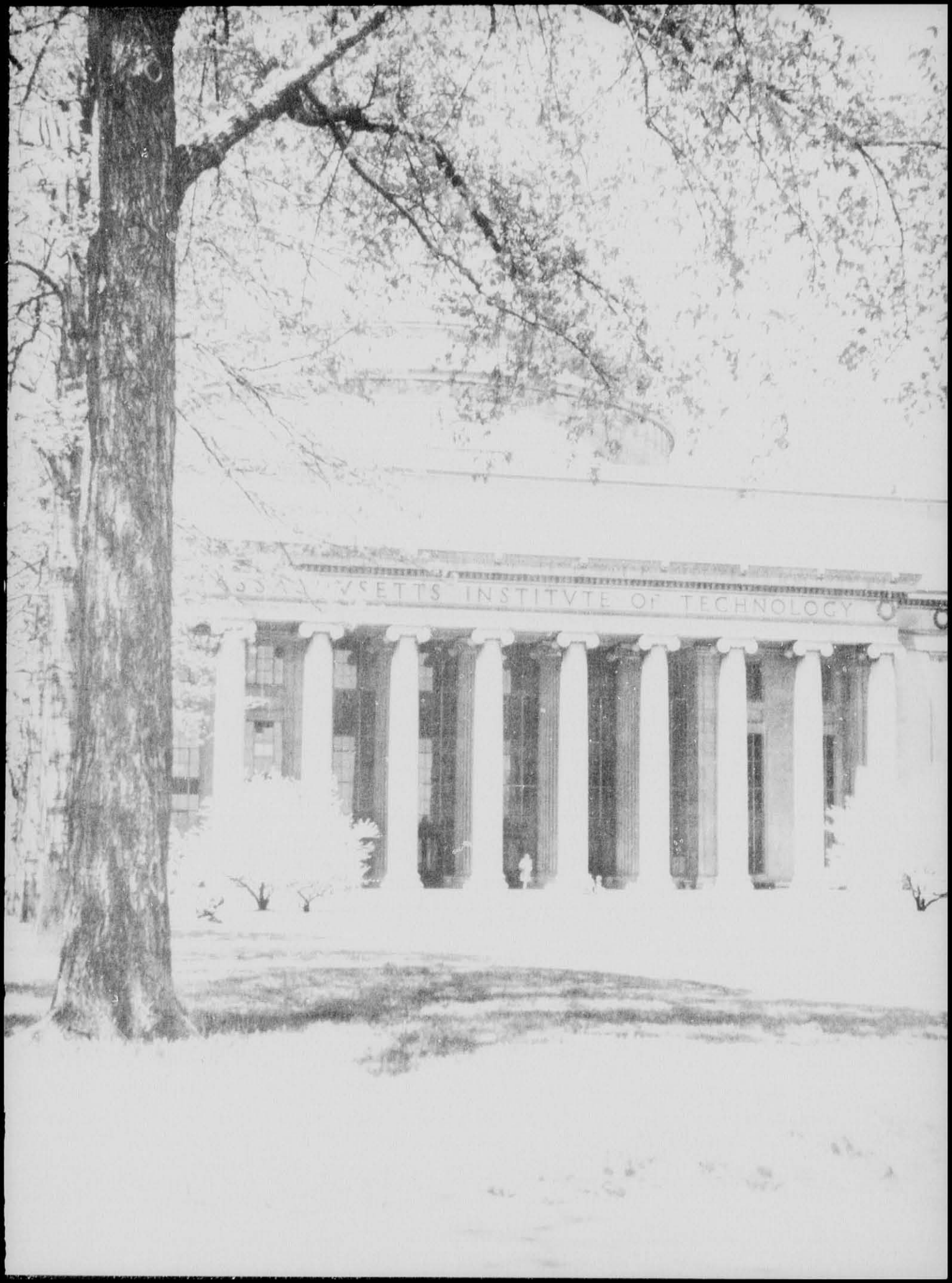
Perspective and Relevance



M.I.T. is a university that has sustained throughout its history an exceptional sense of relevance to its times. Concerned first with the soundness of its scholarship and with the education of its students, the Institute has nourished an innovative interest in the problems of society. And now, perhaps more than ever, it is appropriate that this be so. A century ago, in a society just emerging from a disastrous civil war, full of divisive problems, confronted with urgent pressures, and with a need to establish and reflect the ideals of a young country, William Barton Rogers' statement of the dignity of useful work and the relation of the ablest young people to the most difficult problems of the time was immediately important. I believe that M.I.T.'s record . . . reflects these directions in a new form, with new purpose, and with continued relevance.

HOWARD W. JOHNSON

From the Report of the President 1967.


SETTS INSTITVTE OF TECHNOLOGY



GENERAL INFORMATION: *A Modern University Centered in Science* 1.



The Massachusetts Institute of Technology is an independent, coeducational, endowed institution committed by charter and plan to the extension of knowledge through teaching and research. It is organized into five academic schools — Architecture and Planning, Engineering, Humanities and Social Science, Management, and Science — and a number of interdisciplinary groups. There are about 7,700 students (including about 400 women), more than 3,800 of them studying for undergraduate degrees; about 975 members of the Faculty; and a supporting teaching staff of almost 675. The Institute is located on a well equipped residential campus of 125 acres fronting the Charles River in Cambridge, opposite Boston.

M.I.T. awards Bachelor's, Master's, professional (engineer), and doctoral degrees in a total of 43 Courses; and it provides important programs of postdoctoral and postgraduate study in management, engineering, and the life sciences. From modest beginnings in 1861 as an institution "where young men could learn exactly and thoroughly the fundamental principles of positive science with their leading applications to the industrial arts," the Institute has grown to embrace teaching and research programs of distinction in engineering and the engineering sciences, the physical sciences, architecture and planning, the life sciences, management, and those of the humanities and social sciences most closely related by method or content to modern developments in engineering, science, and mathematics.

A Powerful Curiosity about Things Not Understood

The unique educational opportunities which the Institute presents to undergraduate and graduate students stem from concepts which underlie all its teaching programs and from special qualities which M.I.T.'s character imparts to its entire academic community.

Emphasis on fundamentals and on self-reliance are central in M.I.T.'s educational philosophy. Substantially every subject taught here is influenced by the environment of a scientific and technological institution: a strong

sense of the quantitative and the analytical, a critical analysis of cause and effect, a demand for precision, and a powerful curiosity about things not understood enter every classroom. The Institute's Faculty holds that this kind of education is relevant to any responsible role which its graduates may assume in a society increasingly influenced by technological progress.

The central purpose of the academic programs is to give students a sound command of basic principles, versatility of mind, insight and perspective concerning natural phenomena, the habit of continued learning, and the power that comes from a thorough and systematic method of attack. From these attributes comes the best assurance against professional obsolescence, especially in today's world of rapid technological change.

M.I.T. is widely known for its contributions to new knowledge, achievements of a remarkable research enterprise which is shared broadly by faculty and students. This interlocking of research and teaching gives to M.I.T. an intellectual climate of extraordinary excitement, a spirit of ferment and creative innovation which every student may share.

The Institute has always sought high professional standards for its teaching and research; there is a traditional and established role of stressing excellence. The continuing search for new methods of teaching, rapid assimilation of new knowledge into teaching programs, and constant emphasis on self-criticism are evidence of the Faculty's commitment to maintain and extend the high quality of an M.I.T. education.

Singleness of Method, Diversity of Interest

The Institute has a single campus and a single faculty serving both undergraduate and graduate students. Most of its classrooms and laboratories are in an interconnected group of buildings which facilitate informal interchange between departments and disciplines. Members of the Faculty group themselves for teaching and research very largely according to their interests, and there are interdisciplinary laboratories to provide support in many fields which go beyond the traditional boundaries of a single department. Students, too, though they register (except for freshmen and some sophomores) in specific departments, focus their work much according to their interests, sharing the interdisciplinary activities of the faculty with whom they work.

Though registration and academic requirements tend of necessity to emphasize the procedural aspects of an M.I.T. education, it is important to understand that the academic programs of most students — both undergraduate and graduate — are flexible within broad limits, determined each year by each student himself (in collaboration with a faculty advisor) in response to his own interests and preparation.

Most undergraduates study in at least three of M.I.T.'s schools, many in four, and a few in all five during the four years of their undergraduate work. Graduate students frequently study in two or three of M.I.T.'s five academic schools. Advanced undergraduates often register with graduate students for at least one of their classes; and many undergraduates and almost all graduate students participate, often together, in advanced research. M.I.T. students come from every state in the United States and from at least 70 foreign nations; the proportion of foreign students at the Institute (about 13 per cent) is one of the highest in an American university.

The intermixing of ages, disciplines, and nationalities which is characteristic of the Institute deeply influences the life and experience of every member of this academic community, bringing together students and teachers, metallurgists and physicists, biologists and architects, humanists and engineers, young and old. The result is an academic environment unusual for its singleness of method and purpose and notable for its diversity of interest.

To Foster Qualities of Intellect and Character

The scope of M.I.T. has always been wider than its title, "institute of technology," might suggest, and today the Institute's commitments to the humanities and social sciences are providing an entirely new dimension of scholarship. The increasing impact of science upon our social institutions and upon the conduct of industry and government has been reflected at M.I.T. in the emergence of active teaching and research in fields in which the physical and social sciences most directly interact — fields such as economics, psychology, political science, linguistics, and the history and philosophy of science.

Every M.I.T. undergraduate takes approximately 20 per cent of his undergraduate work in the humanities program, averaging one subject each term. An undergraduate who wants more work in this area may register for a program

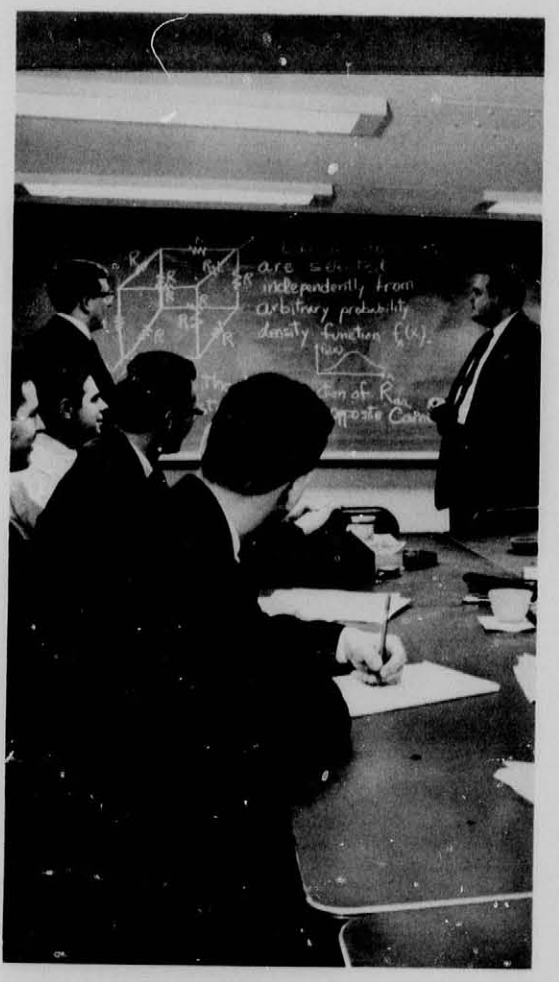
which combines study in one field of humanities or social science with work in one science or engineering discipline, or for a program which permits concentration in humanities alone. Students are eligible for either option after satisfying the Institute requirements in science.

The Institute maintains a commitment to foster for its students those qualities of intellect and character which distinguish truly educated men and women, the qualities of responsibility and ethic which mark the professional estate. In turn, M.I.T. assumes in its students a commitment to adult values which is expressed by extending to them a large measure of responsible self-government and personal freedom.

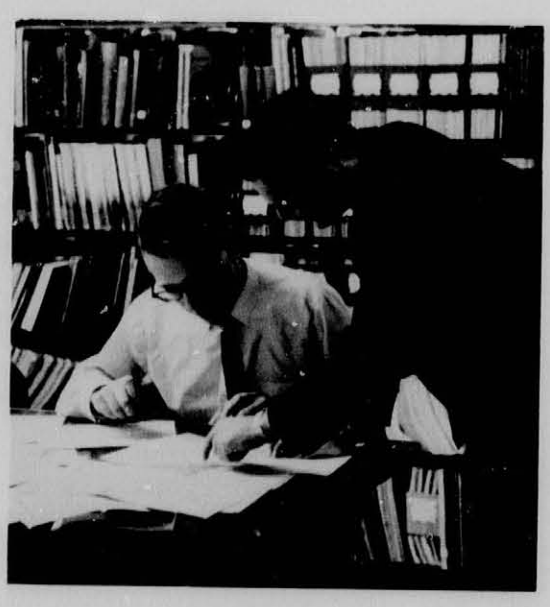
"As a great educational institution," Dr. Julius Adams Stratton, former President of M.I.T., has said, "we shall be judged not only by the quality of our students' intellectual discipline but by the firmness of their moral fiber, by their attitudes toward the whole of learning, by the manner in which they speak and act, and by their understanding of the obligations of a citizen."






are
independently from
arbitrary probability
density function f(x).





The Academic Program

The primary organization of the academic program is along the lines of the traditional disciplines. Each of the 23 academic departments offers one or more degree programs, or Courses[1] of study, and every upperclass undergraduate student and every graduate student is registered in one of these Courses. Degrees are awarded on the basis of satisfactory completion of Courses.

But increasing numbers of students choose fields of concentration which cross regular departmental lines. Among these are programs in fields such as planetary and space science, space technology, communications, materials, computer science, operations research, instrumentation, and others. Some of these involve guidance for the student by standing or special committees; some consist of association with one of the interdepartmental activities described below.

Undergraduate Courses at M.I.T. lead to the degree of Bachelor of Science (S.B.). Graduate degrees awarded are Bachelor in Architecture (B.ARCH.), Master of Science (S.M.), Master in Architecture (M.ARCH.), Master in City Planning (M.C.P.), Engineer (each degree designating the field in which it is awarded),[2] Doctor of Philosophy (PH.D.), and Doctor of Science (SC.D.).

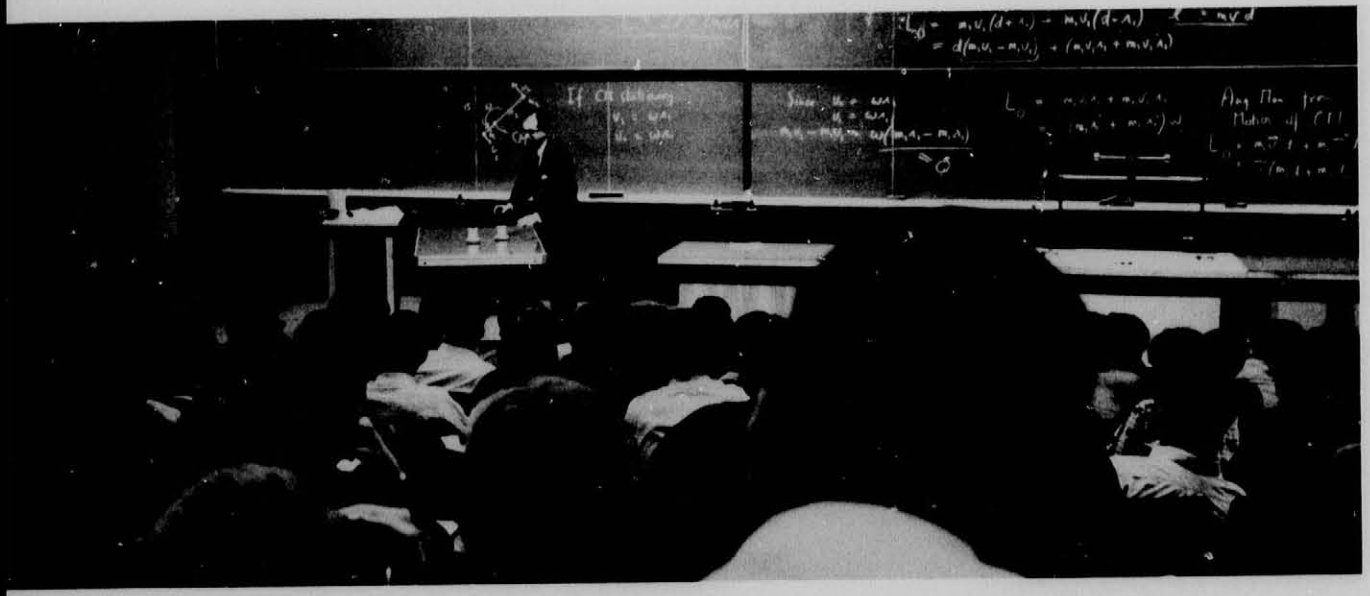
The chart on the following pages shows schools, departments, undergraduate and graduate Courses and degrees, and Course numbers. Undergraduate Courses, including Courses which provide periods of on-the-job experience in industry, require four years of full-time study for the Bachelor of Science degree.

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

[1] At the Institute 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. 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 1.05 indicates a subject given in the Course in Civil Engineering.

[2] The Engineer degrees include 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.), Ocean Engineer (OCEAN E.).



SCHOOLS, DEPARTMENTS, COURSES, AND DEGREES

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

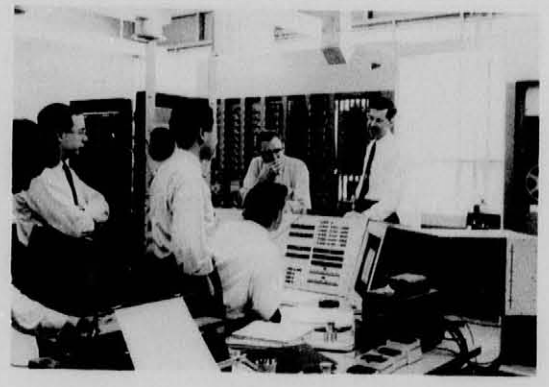
[1] In the field of Materials Engineering, programs leading to the degrees of Materials Engineer (MAT.E.) or Doctor of Science or Doctor of Philosophy are offered under interdepartmental supervision.

[2] See the Department's statement for complete information about the specific degrees offered.

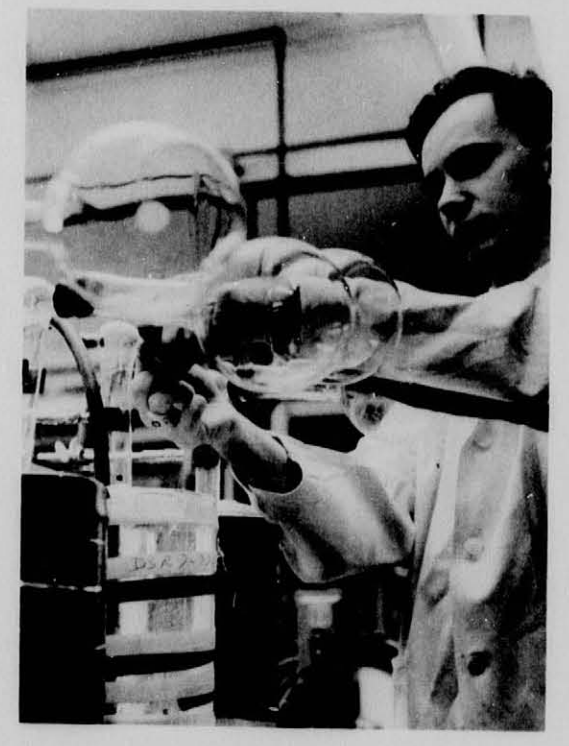
[3] Five-year Course leading to Bachelor of Science and Master of Science degrees awarded simultaneously at the end of the graduate year.

[4] See the statement concerning the specific degrees offered by the Department, as well as the doctor's degrees offered by the Woods Hole Oceanographic Institution and M.I.T. in the Joint Program described at the end of Section 8.

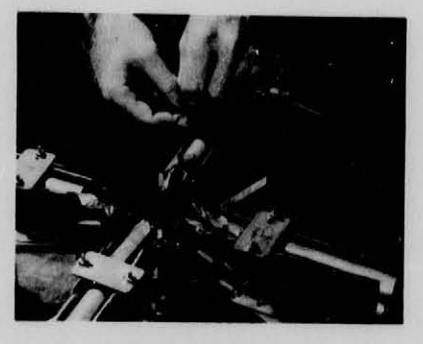
Schools and Departments	*Undergraduate Courses (and Course Numbers)*	*Bachelor's Degrees*	*Graduate Courses*	*Graduate Degrees*
Department of Naval Architecture and Marine Engineering	NAVAL ARCHITECTURE AND MARINE ENGINEERING (XIII)	S.B.	NAVAL ARCHITECTURE AND MARINE ENGINEERING (XIII)	S.M., NAV.ARCH., MAR. MECH.E., SC.D., PH.D.
			OCEAN ENGINEERING	S.M., OCEAN E.
	SHIPPING AND SHIP-BUILDING MANAGEMENT[2,3] (XIII-B)	S.B.	SHIPPING AND SHIP-BUILDING MANAGEMENT (XIII-B)	S.M.
			NAVAL CONSTRUCTION AND ENGINEERING[2] (XIII-A)	S.M., NAV.E.
Department of Nuclear Engineering			NUCLEAR ENGINEERING (XXII)	S.M., NUCL.E., SC.D., PH.D.
School of Humanities and Social Science				
Department of Economics	ECONOMICS (XIV)	S.B.	ECONOMICS (XIV)	S.M., PH.D.
Department of Humanities	HUMANITIES AND ENGINEERING (XXI-A)	S.B.	PHILOSOPHY (XXI)	PH.D.
	HUMANITIES AND SCIENCE (XXI-B)	S.B.		
Department of Modern Languages and Linguistics			LINGUISTICS (XXIII)	PH.D.
Department of Political Science	POLITICAL SCIENCE (XVII)	S.B.	POLITICAL SCIENCE (XVII)	S.M., PH.D.
Department of Psychology			PSYCHOLOGY (IX)	PH.D.
Alfred P. Sloan School of Management	MANAGEMENT (XV)	S.B.	MANAGEMENT (XV)	S.M., PH.D.
School of Science				
Department of Biology	LIFE SCIENCES (VII)	S.B.	BIOLOGY[2] (VII)	S.M., PH.D., SC.D.
Department of Chemistry	CHEMISTRY (V)	S.B.	CHEMISTRY (V)	S.M., PH.D., SC.D.
Department of Geology and Geophysics	GEOLOGY AND GEOPHYSICS[2] (XII)	S.B.	GEOLOGY AND GEOPHYSICS (XII)	S.M., PH.D., SC.D.
	GEOLOGY AND GEOPHYSICS[2,3] (XII-A)	S.B.	GEOLOGY AND GEOPHYSICS[2,3] (XII-A)	S.M.
			OCEANOGRAPHY[4]	S.M., PH.D. SC.D.
Department of Mathematics	MATHEMATICS (XVIII)	S.B.	MATHEMATICS (XVIII)	S.M., PH.D., SC.D.
Department of Meteorology			METEOROLOGY (XIX)	S.M., PH.D., SC.D.
			OCEANOGRAPHY[4]	S.M., PH.D., SC.D.
Department of Nutrition and Food Science			NUTRITION AND FOOD SCIENCE[2] (XX)	S.M., PH.D., SC.D.
Department of Physics	PHYSICS (VIII)	S.B.	PHYSICS (VIII)	S.M., PH.D., SC.D.



THE TX-O DIGITAL COMPUTER



IN THE FOOD SCIENCE LABORATORIES



A COUNTER IN THE RADIOACTIVITY CENTER



POWDER METALLURGY IN THE METALS PROCESSING LABORATORY



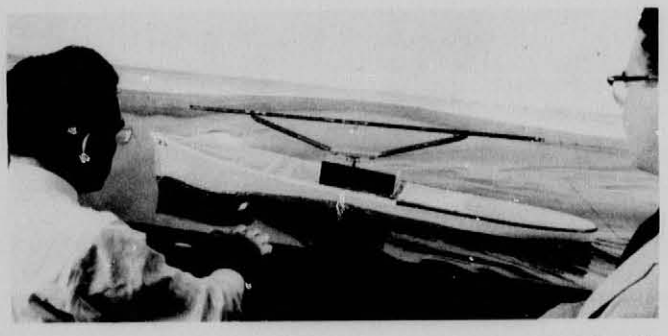
SPECTROSCOPY LABORATORY



THE NATIONAL MAGNET LABORATORY



THE COMPUTATION CENTER



THE SHIP MODEL TOWING TANK

Teaching and Research Resources

Teaching and research both fulfill M.I.T.'s purpose of advancing the frontiers of knowledge, and these activities carried on together have greater power than either performed alone. While advancing human knowledge and understanding, research makes special contributions to the Institute's educational program by providing experience in theory and experiment for both students and faculty and by assuring that classroom teaching is up-to-date; thus research is viewed at M.I.T. as an essential partner with classroom and laboratory instruction.

The Institute receives generous grants from both industry and government in support of research activities in which students and faculty participate, and it devotes substantial resources of its own to such undertakings. For this work M.I.T. has facilities unusual — and in some cases unique — among educational institutions. There are more than 70 special laboratories on the campus in Cambridge. In general, the Institute's policy is to make these facilities available to all scholars — undergraduate, graduate, and postdoctoral — whenever they have a legitimate educational need for them, with the result that nearly all of M.I.T.'s laboratories are shared by undergraduates, graduate students, and faculty working together.

Most of these research facilities are described elsewhere in this book by the departments which operate them. Typical are the nuclear reactor (Department of Nuclear Engineering); the supersonic wind tunnels and Instrumentation Laboratory (Department of Aeronautics and Astronautics); the Electronic Systems Laboratory (Department of Electrical Engineering); and several departmental computation facilities operated by the Departments of Civil, Electrical, and Mechanical Engineering, and the Alfred P. Sloan School of Management.

In addition to laboratories and facilities organized within departments, there are an increasing number of laboratories of an interdepartmental nature, established to facilitate work in fields which cross the lines of traditional disciplines. The most important of these interdisciplinary research activities are described below.

Francis Bitter National Magnet Laboratory

The Francis Bitter National Magnet Laboratory, sponsored at M.I.T. by the U. S. Air Force Office of Scientific Research, provides magnetic fields of extremely high intensity for research in

solid-state, low-temperature, and plasma physics and in related areas of science. The experimental facilities are available to students and faculty from M.I.T. and to scientists from other academic, government, and industrial laboratories. The resident research staff and students conduct experimental and theoretical studies in solid-state and low-temperature physics. Electromagnetic radiation from radio frequencies to gamma rays and a wide frequency range of acoustic waves are employed to probe the properties of matter in intense magnetic fields. Continuous fields up to 250,000 gauss are produced in a variety of water-cooled magnets powered by a ten-megawatt direct current supply. Superconducting magnets are also in use. A hybrid magnet consisting of both superconducting and water-cooled sections is under construction. Pulsed fields exceeding 500,000 gauss are generated by large currents from a capacitor bank.

Cambridge Electron Accelerator

The Cambridge Electron Accelerator, a 6-BeV synchrotron built and supported by funds from Atomic Energy Commission contracts, is operated jointly by M.I.T. and Harvard for research in particle physics by faculty and students from both institutions and other qualified scientists.

Center for International Studies

The Center for International Studies reflects the strong interest of M.I.T. in the social, political, and economic problems of the contemporary world. Although the Center has no teaching program of its own, most of its senior staff are faculty members of the Departments of Economics and of Political Science; the Center provides research opportunities that are important to the professional development of the departments. There are also opportunities for graduate students to participate in the Center's research programs.

Current research includes studies on economic and political development of nations in Asia, Africa and Latin America, international communications, Communist and radical movements, arms control, and various aspects of American foreign and defense policy.

Center for Materials Science and Engineering

The Center for Materials Science and Engineering is an interdepartmental activity providing a central focus and expanded facilities for teaching and research on the preparation, structure, properties, and applications of materials. Programs in materials research are conducted in many departments of the Institute, six of which now offer advanced degrees in materials. These activities are described in the *Annual Report on Materials Science and Engineering at M.I.T.*, available upon request to the Center. Students registered in any of the related departments may combine advanced training in the specific discipline of the department with experience in materials science and engineering through participation in the work of the Center.

A new laboratory building provides accommodation for research and central facilities for the preparation and analysis of materials, including crystal growth. Faculty from a number of departments of the Schools of Engineering and of Science occupy this laboratory, which provides an interdisciplinary environment for diverse activities in materials research and teaching. The Advanced Research Projects Agency of the Department of Defense, in addition to providing part of the funds for the construction of the new building, also provides operating funds to stimulate new programs in advanced areas of materials research.

Center for Space Research

The Center for Space Research has been formed to stimulate graduate education and research in space-related disciplines in many departments at M.I.T. The Center administers funds for specific and collaborative space studies and experiments. It also provides facilities and engineering support for the development of space payloads and assists in the reduction and interpretation of astrophysical data.

A new building to house the Center's principal activities recently has been completed on the north campus. Both the building and the research program have been financed in part by the National Aeronautics and Space Administration.

Graduate Studies in Engineering and Living Systems

Students and faculty in many departments at M.I.T. are conducting research in Engineering and Living Systems. These research interests, arising in the biological, engineering, and social sciences, have led to programs of graduate study for students wishing to pursue careers in these rapidly evolving fields. The spectrum of academic and research programs is extremely

broad, ranging from basic physiological studies and the development of new medical and biological techniques with related engineering analysis and design, to problems in urban structure and planning, such as the design of new systems for the delivery of health services. Each of these programs, although strongly interdisciplinary in nature, has grown out of the interests and professional specialties of the participating faculty. Thus, students can enter these programs through various departmental routes.

In addition to the large number of investigations in the biological and medical sciences being carried out within the Departments of Biology, and Nutrition and Food Sciences, there are active programs of research in Engineering and Living Systems within the following departments: Aeronautics and Astronautics, Chemical Engineering, Chemistry, City and Regional Planning, Electrical Engineering, Mechanical Engineering, Metallurgy and Materials Science, Modern Languages and Linguistics, Nuclear Engineering, Physics, and Psychology. Virtually all of these studies are collaborative, involving interdepartmental cooperation as well as active support and participation by faculty of the medical schools in the Boston area and the affiliated teaching hospitals.

To serve as an advisory body to students in Engineering and Living Systems, the Dean of the School of Engineering has established a Steering Committee drawn primarily from the Engineering faculty with representatives from other Institute departments and academic centers. In addition to its advisory functions, this Committee provides an effective mechanism for interdepartmental and interorganizational communication through meetings, invited lectures and seminars.

Information Processing Services

Computation at M.I.T. touches all aspects of the university: teaching, research, and administration. Drawing upon two decades of experience with digital computers, members of the M.I.T. Faculty, and research and administrative staffs continually seek to develop and exploit computer capabilities in all three areas.

Students, both undergraduate and graduate, are intimately involved in much of this activity. A large majority of students begin to use the computer early in their programs of study and many continue to do so on into graduate work. Specific opportunities to pursue programs oriented toward the computer sciences are described elsewhere in this Bulletin.

The Information Processing Services Center is a large and versatile computer facility whose purpose is to meet the teaching, research and administrative needs for information processing of all members of the Institute community. The Center offers its users a broadening spectrum of information processing services, including standard batch processing, remote-job-entry batch processing, on-line file manipulation, and general purpose, interactive time sharing. The central facility includes an extensive IBM System/360 complex housed in new quarters completed in the summer of 1968.

Also available is a specially modified IBM 7094 installation, which has been providing general-purpose time sharing to the campus and the New England colleges since mid-1963. The operating system software for this facility is the M.I.T. Compatible Time Sharing System (CTSS), developed in the Center by Professor Fernando J. Corbató and his staff. First demonstrated in 1961, CTSS was revised and extended during 1963-1966 as part of the research of Project MAC. One of the earliest time-sharing systems, and one of the most general yet developed, CTSS has been regarded since 1966 not as a focus for a program of research, but as a service facility. In this role it has become a resource upon which a number of research and instructional programs depend.

The Center is a key component in the growing, campus-wide information processing capability of M.I.T., which now includes, in addition to the Center, some nine distinct computer facilities that are physically located near user "clusters." With this approach, some of the specialized local needs of the community can be met with small or specially tailored computers; these local facilities are then backed up by the large general-purpose installation of the Center. This same concept extends to more than 60 colleges and universities in New England that are cooperating with M.I.T. in the development of regional computer capabilities.

A number of the smaller computers, both on the M.I.T. campus and on the campuses of other New England colleges, can be connected directly by data-communication circuits either to the main computer or to each other. This interconnected, mutually supporting complex is being continually developed in order to provide high quality computer service to all users.

General

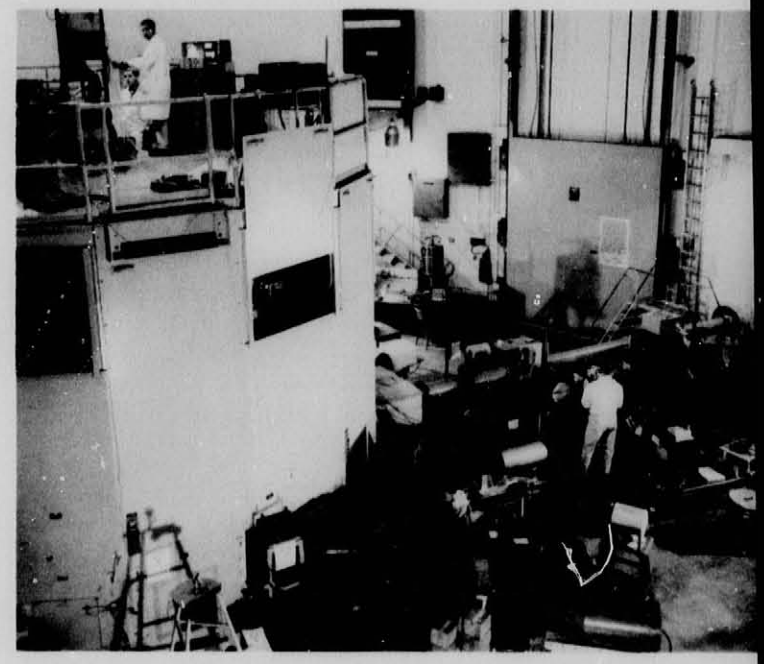
Joint Center for Urban Studies of M.I.T. and Harvard University

The Joint Center was established in 1959 to link urban research activities at M.I.T. with similar activities at Harvard and to develop a new level of interest in urban and regional studies at both institutions. The Center maintains offices at 66 Church Street, Cambridge (02138), encourages basic and applied research on the problems of cities and regions, and sponsors colloquia, seminars, and professional conferences.

The Joint Center provides important research opportunities for faculty members and advanced graduate students at both institutions. Research areas of current interest include problems of transportation, housing, urban design and technology in relation to urban and regional development.

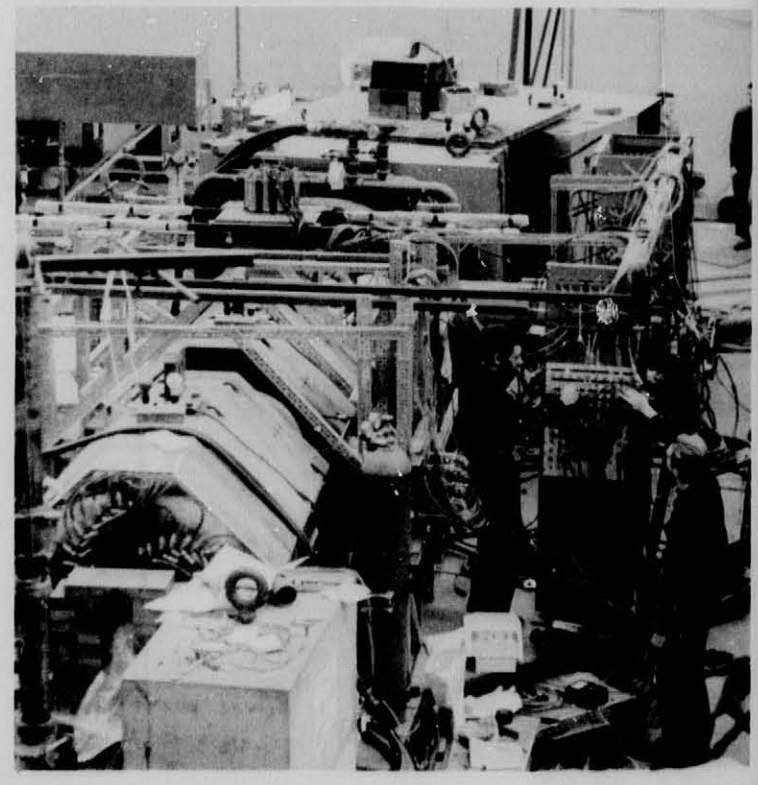
Laboratory for Nuclear Science

The Laboratory for Nuclear Science performs basic research in nuclear physics and chemistry, supporting research interests of faculty in the Departments of Physics and Chemistry by maintaining and administering a number of special research facilities. Its major equipment now includes two particle accelerators: a 7-MeV proton cyclotron, and a Van de Graaff positive ion accelerator capable of producing particles with energies up to 10 MeV; many other experimental facilities are also available. A 400-MeV, high-intensity electron linear accelerator is expected to be available for nuclear physics research by 1970. This will extend greatly the Laboratory's capabilities in this field. In addition, the Laboratory operates its own computer (IBM 360-65) as an open-shop facility available to staff and students. 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, spark chambers, and complex electronic hodoscopes; studies of cosmic rays, including a program oriented toward the astrophysical aspects of these rays using space satellite vehicles; programs oriented toward the application of high-speed electronic computer techniques to the problems of nuclear and elementary particle 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



THE M.I.T. REACTOR

A LARGE SCINTILLATION COUNTER AT THE CAMBRIDGE ELECTRON ACCELERATOR



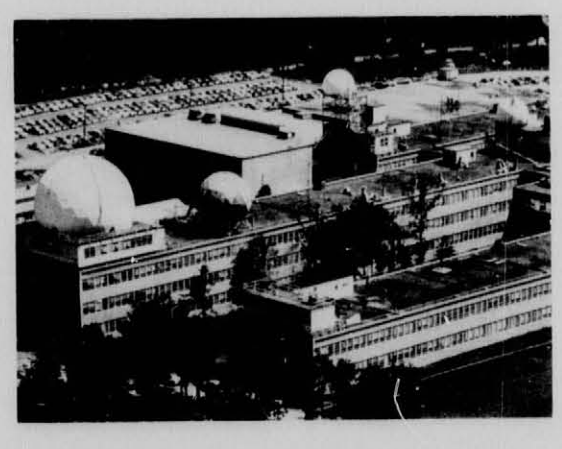


PROJECT MAC



COMMUNICATIONS BIOPHYSICS

LINCOLN LABORATORY



in experiments in high-energy physics at the Brookhaven and Argonne National Laboratories as well as at the Stanford Linear Accelerator. Experiments are also under way in conjunction with the 6-BeV Cambridge Electron Accelerator.

Lincoln Laboratory

The Lincoln Laboratory, located in Lexington, Massachusetts, is a Federally sponsored center for research and development in advanced electronics, with special emphasis on applications to national defense and space exploration. The Laboratory, which derives its current support largely from the Department of Defense, is staffed and operated by M.I.T.

The work of the Laboratory consists of programs undertaken in response to requests of government agencies whose needs coincide with the Laboratory's fields of competence as well as a program of general research. Programs in areas directly related to defense and space objectives include re-entry technology and communications. Another program is concerned with the development of techniques for discriminating reliably at great distances between underground nuclear tests and natural seismic events. General research is conducted in the fields of solid state, data systems, radio physics and astronomy, radar, and communications.

In many technical areas, the facilities of Lincoln Laboratory are available for research by M.I.T. faculty members and advanced graduate students.

Project MAC

Project MAC is an interdepartmental facility devoted to research in the computer and information sciences. The name MAC is an acronym derived from two titles: machine-aided cognition and multiple-access computer. The broad goal of machine-aided cognition implies the development of new ways in which on-line use of computers can aid people in their creative work, whether it be research, engineering design, management, or education. Thus, a major research topic is the evolutionary development of a large, time-shared computer system that is easily and independently accessible to a large number of people and responsive to their individual needs. This development includes consoles with graphic as well as alphanumeric displays, languages for the preparation of computer programs and for on-line communication with the computer, service programs to assist the user in a great variety of activities, and data

banks for the storage and retrieval of useful information. Another major research topic is the development of general purpose "eyes" and "hands," together with analytical and integrative procedures corresponding to visual perception and manual control, by means of which a computer may interact with its physical environment. These two specific efforts are supported and supplemented by a program of basic research on various theoretical aspects of computing and information processing.

The initial MAC computer system, including a modified IBM 7094 computer and other equipment, provides simultaneous and independent access to a large number of remote users operating through teletypewriters and other terminals. The system is continuously evolving as new programming facilities and other features are added to it. Experience gained from the operation of this first time-sharing system, combined with knowledge gained from recent basic research, has led to the design of a second-generation system, MULTICS (for Multiplex Information and Computing Service), which is currently being implemented for the G.E. 645 computer. This new system, which incorporated various novel features and techniques intended to increase its efficiency of operation and to facilitate man-machine interaction, is expected to be available for general use by the end of 1968.

Research Assistantships are available for work in all aspects of the research program supported by Project MAC. Also, facilities are provided for thesis research and special projects on the part of both undergraduate and graduate students.

Project MAC is sponsored by the Office of Naval Research on behalf of the Advanced Research Projects Agency.

Operations Research Center

The Operations Research Center, an interdepartmental activity, affords an opportunity for graduate students to combine work on actual operations research problems with the pursuit of theoretical knowledge in this rapidly developing field. Since its founding in 1953, the Center has sponsored research in the fields of dynamic probabilistic systems, mathematical programming, queuing, inventory and storage systems, and simulation of operational systems; and has carried out field investigations in various areas including transportation, traffic, educational, and municipal services. Present interests are particularly focused on the study of public systems. The research grants and contracts administered by the Center provide support for graduate thesis research, and the Center supervises graduate programs of study in operations research leading to Master's or doctoral degrees. Some graduate students prefer to work mainly in the department of their registration, taking the examinations and subjects required for a graduate degree in that department and obtaining operations research experience by taking elective subjects and conducting their thesis research in this field. Doctoral students who desire to concentrate more heavily in operations research may arrange for interdepartmental supervision of their graduate programs by special faculty committees.

GREEN BUILDING (EARTH SCIENCES)



Research Laboratory of Electronics

The Research Laboratory of Electronics provides a basic research environment with participation of faculty and students from a dozen academic departments. Since the formation of the Laboratory in 1945, as an outgrowth of the M.I.T. Radiation Laboratory, the research program has evolved and broadened. At present, the activities of the Laboratory fall into three principal categories. These are general physics, plasma dynamics, and communication sciences. Among the research activities in general physics are microwave, optical, and infrared spectroscopy, radio astronomy, molecular beam studies, and microwave electronics. The research in plasma dynamics includes basic studies of plasma physics and gaseous electronics, as well as applications such as controlled fusion for energy conversion, ion propulsion, and microwave devices.

The research in communication sciences involves studies of both living and man-made systems. The major areas of interest in communications bioengineering include communications biophysics, neurophysiology, speech communication, linguistics, and cognitive information processing. Other communications studies include information processing and transmission, statistical communication theory, artificial intelligence, circuit theory, and computer research.

Both graduate and undergraduate students participate in the full range of activities mentioned above.

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 throughout the optical range of the spectrum from the vacuum ultraviolet to the far infrared. These instruments are used in studies of molecular geometry, the properties of solids and liquids, and the interactions of molecules of importance to biology. Investigations are in progress in the application of lasers to such problems as excitation of Raman spectra from very small samples of biochemicals and generation of Brillouin scattering in liquid and solid systems of special interest.

Urban Systems Laboratory

The Urban Systems Laboratory was started in 1967 and is evidence of the Institute's intention to organize and bring to bear its resources on the problems of the urban areas. The Laboratory is an interdepartmental and multidisciplinary federation of individuals — students, faculty, and staff members — groups, laboratories, and departments with interests and activities in the area of urban systems. The area of urban systems can be defined as the advancement and utilization of the methods of systems analysis, systems engineering, information systems, and related advanced capabilities and technologies as applied to the facilities required for urban living, including among others transportation, education, communication, environmental quality control, and health.

The Laboratory is developing an environment and mechanism for helping the individual faculty member and his students pursue their interests in urban systems, is helping the various departments and schools build focal point groups and is helping them become active in the area of urban systems; it is developing urban systems research resources and capabilities that will assist the faculty. The Laboratory is promoting the development of creative interactions with urban organizations that can apply the results of urban systems research and can help in the process of defining needs and problems. The objective of the Laboratory over the intermediate range is to develop an Institute capability for playing a significant role in large-scale, mission-oriented, action-oriented projects in the area of urban systems.

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 full list of these Committees on Joint Research Areas, including communication sciences, information processing, operations research, radio astronomy, and solar energy, appears at the back of this Catalogue.

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.

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 programs of study combining academic work at

M.I.T. with on-the-job practice in industry. In chemical engineering, the School of Chemical Engineering Practice operates stations for undergraduates and graduate students at the Bound Brook, New Jersey, plant of the American Cyanamid Company and at the Oak Ridge National Laboratory and it also provides other opportunities for students to obtain practical experience in industry.

In a very real sense, these activities extend the M.I.T. campus into a number of industrial plants throughout the country.

Organization of the Institute

The governing body of the Institute is a board of trustees known as the Corporation, over which the Chairman presides. Its members include more than 60 distinguished leaders of science, engineering, industry, and education and (*ex officio*) the President and Vice President and Treasurer of the Institute. Between quarterly meetings the Corporation functions through its officers and Executive Committee.

The Corporation appoints Visiting Committees for each department and for certain of the other major activities 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 Institute's chief executive officer is the President. In addition, senior officers include the Provost and seven Vice Presidents. The academic program is directed by the President, the Provost, and five deans, each responsible for the undergraduate and graduate programs in one of the five academic schools.

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 and the M.I.T. Associates Office are 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 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 academic staff of the Institute — including instructors, research associates, and graduate, teaching, research, and technical assistants who are not members of the Faculty — totals about 3,000.

The Campus

M.I.T.'s 125-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 holdings in excess of one million volumes, the M.I.T. Libraries are a vital resource for the support of both teaching and research. Nearly 9,500 current journals and serials and 1,500 government document series, together with extensive back files, provide comprehensive holdings in all major fields. These are enriched by numerous special collections, including a large group of technical reports, and the Institute archives.

The library system, with headquarters in the Charles Hayden Memorial Library building, includes five school libraries, three branches, and four reading rooms: the Rotch Library of Architecture and Planning; the Dewey Library (economics, industrial management, industrial relations, and political science); the Engineering Library (with a separate aeronautics and astronautics branch, materials science reading room, and space research reading room); the Humanities Library (with a branch music library and

a reserve book room); and the Science Library (with the Lindgren Library branch for the earth sciences); and the Student Center Reading Room.

All the services offered by a fine research library are available: reference and information, interlibrary loans, and microfilms, photoprints, and quick copies of works here or in other libraries.

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

Exhibitions and Activities in the Visual Arts

The Office of Exhibitions presents approximately eight major exhibitions a year in the Hayden Gallery and sculpture courtyard, with emphasis on contemporary art. Exhibitions in 1967–68 included recent work of the kinetic artist Hans Haacke, paintings of Jules Olitski, and an environmental installation in several areas in the Institute of paintings and sculpture by New York's Park Place Group. Some additional and usually smaller exhibitions are departmentally oriented and installed in the lobby of the Hayden Gallery, in the Rogers Building Lobby, the Creative Photography Studio, the Student Center, and other suitable areas of the Institute.

The Francis Russell Hart Nautical Museum, housed in the Department of Naval Architecture and Marine Engineering, contains a fine collection of ship models and the Allan Forbes and Arthur H. Clark print collections.

The M.I.T. permanent Art Collection, which now includes nearly 300 paintings, indoor and outdoor sculpture, and graphics, is distributed throughout the Institute. The Catherine N. Stratton Collection of Original Graphics is reserved for student use in living and activity areas. Recent acquisitions for the Institute Collection include major paintings by Gene Davis and Jules Olitski, outdoor sculpture by Ipousteguy and David von Schlegell, and a 40-foot stabile, *La Grande Voile*, by Alexander Calder; the latter is in McDermott Court, adjacent to the Hayden Library and the Green Building.

In addition, the Office of Exhibitions sponsors art lectures, films, exhibition openings, and panel discussions with artists exhibiting at the Institute.

Recreation

Athletic and recreational 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.

The new Student Center, the Julius Adams Stratton Building, providing social rooms, restaurants, offices for student activities, game rooms, a large reading room, music rooms, and a number of stores, is the center of student social life.

Playing fields for soccer, lacrosse, baseball, softball, touch football, rugby, cricket, 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 an indoor track and a portable basketball floor and stands; the Briggs Field House, with lockers and showers to serve the nearby playing fields and Rockwell Cage; an outdoor artificial-ice rink, used from November through March; and the David Flett du Pont Athletic Center, with new facilities for squash, wrestling, fencing, judo, pistol, rifle, and gymnastics, and locker rooms for both men and women. The athletic offices are on the second floor of the du Pont Building. An excellent indoor swimming pool is open throughout the year, and there are a number of squash courts nearby.

The Pierce Boathouse on the Charles River is complete with eight-oared racing shells, fours, pairs, double and single sculls. 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 at 80 Haven Street in Dedham, is M.I.T.'s center for

General

STUDENT HOUSING

off-campus educational and administrative conferences. Set in spacious grounds, the House has meeting and dining rooms for 75 guests and overnight accommodations for 31.

Student Housing

UNDERGRADUATE RESIDENCE

At the undergraduate level, the Massachusetts Institute of Technology is essentially a residential university. Of the total undergraduate student body of about 3,800, about 1,700 single men live in six men's residences on or near the campus; about 200 single undergraduate women live in the women's residence, McCormick Hall, on the campus; and about 1,300 single men live in 28 fraternity chapters and the cooperative M.I.T. Student House. The men's and women's residences are generally called the "Institute Houses."

The central purpose of the residential system is to provide environment and programs conducive to personal development as well as to academic achievements and in this way to extend the experience of higher education which M.I.T. offers its undergraduates. Great reliance is placed by the Institute on the initiative and responsibility of both individual students and student government organizations in the residences.

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

Determination and maintenance of living conditions in the residences are the responsibility of the Dean of Student Affairs and the Office of Campus Housing, in cooperation with student governments and those members of the faculty in residence. Many responsibilities are delegated to student governing groups for establishing and administering House regulations and acceptable standards of community behavior.

Residential student governments also organize a wealth of social, athletic, and intellectual programs for House members. In the Institute House system a House Tax which is included in each resident's rental fee is turned over to the Dormitory Council — a federation of the Institute House governments — to help support these



THE DORRANCE LABORATORY FOR BIOLOGY AND FOOD SCIENCE

THE CHARLES HAYDEN MEMORIAL LIBRARY



THE GUGGENHEIM AERONAUTICAL LABORATORY



THE STEIN CLUB MAP ROOM



MUSIC LIBRARY





THE HAYDEN GALLERY



ALUMNI SWIMMING POOL



KRESGE AUDITORIUM



M.I.T. CHAPEL



activities. Individual fraternity chapters have similar taxes to support their extracurricular programs.

The Institute believes that it is to the great advantage of all undergraduates who do not live at home to reside "on campus" — that is, to live in an Institute House, one of the 28 recognized fraternities, or the M.I.T. Student House. Freshmen particularly gain from associations with upperclassmen and participation in residence programs. Therefore, insofar as accommodations permit, all unmarried freshmen who cannot commute daily from their own homes or those of close relatives in the Greater Boston area are required to live "on campus." All unmarried undergraduate women students are required to live in McCormick Hall unless they reside at home with their families or, in the case of seniors, have parental permission to reside off campus. Exceptions to these "on campus" living requirements are made only with the specific approval of the Dean of Student Affairs.

The Undergraduate Houses for Men

The Everett Moore Baker House, located on the river front at 362 Memorial Drive, Cambridge, west of Massachusetts Avenue, accommodates some 370 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, also on the river front at 410–420 Memorial Drive, Cambridge, west of Baker House, accommodates about 540 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.

Bexley Hall, an apartment house at 46–48–50–52 Massachusetts Avenue, directly across from the main entrance to the Institute, has been furnished as an apartment dormitory for men. There are suites for two, three, and four students, each with bath and kitchenette, and a total of about 130 men can be accommodated.

Random Hall, located on Massachusetts Avenue three blocks north of the campus, accommodates 100 men in suite-style apartments. A normal suite accommodates 14 men in one- and two-man rooms and contains common bath, kitchenette, and lounge facilities. Residents may, if they wish, take their meals at any of the Institute's dining facilities.

The Senior House—Ware, Atkinson, Runkle, Holman, Nichols, and Crafts — on Memorial Drive, east of Walker Memorial and adjacent to the President's House, accommodates about 200.

The East Campus Houses — Munroe, Hayden, Wood, Goodale, Bemis, and Walcott—near Walker Memorial have accommodations for about 410.

Dining facilities for residents of the Senior House and the East Campus Houses are in the Walker Memorial Building. They include a large cafeteria, where both commons meals and a 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.

Rooms in the Institute Houses for undergraduate men are engaged for the full academic year. For the year 1968–69, the residence fees

THE HAYDEN LIBRARY



ENDICOTT HOUSE

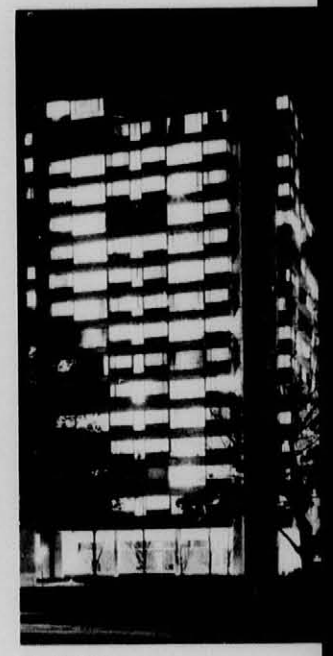




BURTON HOUSE



BAKER HOUSE



WESTGATE

SENIOR HOUSE



MC CORMICK HALL



range from $185 to $250 per term. Commons meals for men are served Monday through Friday — 15 meals per week, on an "unlimited seconds" basis. Election of the commons plan is for the full term in which it is made. For the academic year 1968–69, the commons fee is $267.75 for the fall term and $252 for the spring term.

Residence for Undergraduate Women

Stanley McCormick Hall, the new undergraduate women's residence, located at 320 Memorial Drive overlooking the Charles River, has accommodations for 221 women students in single and double rooms. All unmarried undergraduate women who do not live at home, with the exception of seniors with parental permission to live off campus, are required to reside in McCormick Hall. In addition, for the academic year 1968–69, about 20 single graduate women will be accommodated.

In McCormick Hall, residence is contracted for an academic year from September to June and includes 20 meals per week during this period (excluding vacations). The residence fee is $1 150 for the 1968–69 academic year and includes blankets for the year and fresh bed linen weekly.

Other Housing Facilities

FRATERNITIES

Recognized fraternities at the Massachusetts Institute of Technology include 27 chapters of national fraternities and one local residential group with no off-campus affiliation. All of the fraternities maintain houses in Cambridge, Boston, or 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 advisors and several chapters have resident graduate student tutors.

Each fraternity chapter is self-governing and is responsible for management of all its operations and maintenance and for development of its academic, social, membership, recreational and external relations policies and programs. The fraternities provide a unique experience in leadership, community planning, and group interactions.

Approximately 90 per cent of the fraternity freshmen are pledged during "Rush Week," which is held in September just prior to Freshman Weekend. Usually about 700 freshmen attend Rush Week and about 350 of them pledge fraternities. A few upperclassmen, including college transfer students, also pledge fraternities at the beginning of each term.

COOPERATIVE LIVING

The M.I.T. Student House is an independent, cooperative living group sponsored by a group of House alumni. The 34 undergraduate members maintain the residence and do all the work except for cooking and major repairs. Cooperation by the students extends to the management of the House and to the academic, recreational, and social aspects of student life. Savings per member are about $400 a year.

The Non-Resident Student Association

Those unmarried undergraduate men who commute daily from their own homes or off-campus quarters and who are not affiliated with one of the Institute Houses, fraternity chapters, or the M.I.T. Student House are considered members of the Non-Resident Student Association (the



N.R.S.A.). A small fee is charged members to help support the social and cultural programs undertaken by this student organization.

The focus for N.R.S.A. activities is a house on the campus which provides social and study facilities for commuting students and limited overnight accommodations. A graduate student tutor is in residence in the house, and the student governing group has responsibilities similar to those of the student governing bodies in the residences.

Additional Information

Additional information on floor plans, fees, regulations in undergraduate housing, and application procedures is contained in the publication *Undergraduate Residence at M.I.T.* Each new first-year student and each new college transfer student is automatically sent a copy of this brochure about three months before registration day of the term for which he has been admitted to M.I.T. Others may request copies from the Office of the Dean of Student Affairs, Room 7-133, M.I.T., Cambridge, Massachusetts 02139. Information on fraternities may also be obtained by writing to Interfraternity Conference, Room W20-413, M.I.T., Cambridge, Massachusetts 02139. Information on the M.I.T. Student House may be obtained by writing to the President, M.I.T. Student House, 111 Bay State Road, Boston, Massachusetts 02215.

GRADUATE STUDENT RESIDENCE

Although the graduate student body numbers about 3,900, a comparatively small number reside on the campus. About 400 single men and 30 single women are accommodated in Ashdown House. In addition, for the 1968–69 academic year, about 20 graduate women will be accommodated in McCormick Hall, the Institute's new undergraduate women's residence. Housing for married students and their families is available in two modern apartment complexes, Eastgate and Westgate, at the east and west ends, respectively, of the M.I.T. campus. Westgate accommodates 210 families and Eastgate 204. For graduate students who reside off campus, the M.I.T. Community Housing Service will assist in locating suitable accommodations.

The Avery Allen Ashdown House

Ashdown House is the primary graduate residence of the Institute for single graduate students; the House is located on the corner of Massachusetts Avenue and Memorial Drive directly across from the main buildings of M.I.T. and adjacent to the West Campus plaza, which is surrounded by Kresge Auditorium, the Chapel, the Stratton Student Center, the du Pont Athletic Center, and the athletic fields.

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 many facilities for social and cultural activities in Ashdown House make it a center of graduate student activities.

Rooms in Ashdown House are engaged for a full academic year; rents range from $160 to $235 per term.

The main dining room provides a la carte cafeteria service Monday through Friday, except during certain vacation periods, and contract meal service for those who may choose to purchase this service. For the academic year 1968–69, the cost of the contract is $267.75 for the fall term and $252.00 for the spring term.

Cafeteria and restaurant food service is also available seven days a week during the regular academic year at the Student Center.

More complete information is found in *Graduate Residence at M.I.T.*, which is automatically mailed to all entering graduate students.

In general, accommodations in Ashdown House 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.

Stanley McCormick Hall

For the academic year 1968–69, approximately 20 rooms will be available for assignment to graduate women in Stanley McCormick Hall, the Institute's new undergraduate residence. This building is located on Memorial Drive immediately west of Ashdown House. Graduate women who reside in McCormick will be expected to take their meals on the commons plan in the House dining room together with the undergraduate residents. Residence is contracted for the academic year from September to June and includes 20 meals per week during this period (excluding school vacations). The total charge is $1,150 for the academic year 1968–69.

Graduate women who are interested in applying for residence in McCormick Hall should write to Professor Emily L. Wick, Associate Dean of Student Affairs, Room 5-106, M.I.T., Cambridge, Massachusetts 02139.

MARRIED STUDENT HOUSING

Two modern apartment complexes, one at either end of the M.I.T. campus, contain a total of 414 family units for married students and faculty couples.

Residence in married student housing is limited to regular undergraduate and graduate married students registered and attending M.I.T. for at least two terms of each year. The summer session is considered a term. Assignments are made on a one-year lease basis. Rents range from $104 to $195 per month including utilities and heating.

A nursery school, with one classroom in Westgate and two in Eastgate, is operated by Technology Nursery School, Inc., a non-profit student-faculty organization; it is open to children of students residing off-campus as well as those residing in Westgate and Eastgate.

Married student housing is managed by the Campus Housing Office, Room E18-307, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139. Since accommodations in Eastgate and Westgate are limited, married students are well advised to contact the Community Housing Office regarding off-campus housing.

Westgate

Five buildings, completed in 1963 and known as Westgate, are at the west end of the M.I.T. campus; they provide 210 modern unfurnished apartments. The West Campus location near Memorial Drive and the Charles River is within ten minutes' walk of the Institute's main buildings.

The complex includes a 16-story tower with 90 one-room efficiency apartments and 60 one-bedroom units, and four three-story garden-type buildings with a total of 60 two-bedroom apartments. Community facilities are available and free parking is provided for a majority of the residents. Rents in Westgate range from $104 to $147 per month.

Eastgate

Located adjacent to Kendall Square at the east end of the M.I.T. campus is Eastgate, a new 30-story apartment tower with 204 family units for married students and faculty. The site adjoins the Alfred P. Sloan Campus with the School of Management, and the Departments of Economics and Political Science. It is convenient to the main campus and public transportation.

The tower building contains 96 one-bedroom apartments, 84 large one-bedroom apartments, and 24 two-bedroom apartments. About 75 per cent of the apartments are allotted to married students; the remainder are available to faculty members. Rents in Eastgate range from $115 to $190 per month. Community facilities are available and free parking is provided for a majority of the residents.

COMMUNITY HOUSING SERVICE

Married students, single upperclass men, and single graduate men and women who do not live on campus will find help in locating accommodations in the Community Housing Service. Listings of available rentals in Cambridge and the Greater Boston area are maintained, and the staff attempts, on an individual basis, to help students locate the type of accommodations that will best suit individual preferences and financial resources and to advise on many additional aspects of off-campus living.

The Community Housing Service is located in Building W31 at the corner of Massachusetts Avenue and Vassar Streets. All correspondence should be addressed to Community Housing Service, Box 42, M.I.T. Branch Post Office, Cambridge, Massachusetts 02139.

Campus Activities

M.I.T. is a community with wide extracurricular interests and liberal opportunities to enjoy them. More than one hundred student-directed activities supported by excellent facilities and capable staff provide the student with opportunities to develop his interests, to acquire new skills and talents and most important, to participate actively in the life of the M.I.T. community.

Lectures, music, drama, art, athletics, and hobbies all make for a many-sided and busy campus. Moreover, Greater Boston provides a wide range of cultural activities to enrich further the total college experience.

Student Government

The M.I.T. Undergraduate Association, comprising all undergraduate students, is responsible for major areas of undergraduate life. The core

agency of the Association is its elected legislative body, the 18-member Institute Committee, which determines association policy and procedures and sponsors a variety of functions and operations. Various subcommittees of the Institute Committee deal with specific aspects of these responsibilities. The Student Committee on Educational Policy makes recommendations to the Faculty concerning academic matters. The Student Center Committee plays a key role in the management of the Student Center. The Student Committee on Environment works to make the campus a pleasant place to live and work. The International Students' Council coordinates the activities of the various nationality clubs. The Activities Executive Board, an administrative group, represents the interests of more than one hundred student activities and seeks to improve the program and scope of each group. The budgets and expenditures of all student organizations are coordinated by the Finance Board, which annually allocates a budget of over $100,000 to support both the work of these subcommittees and the programs of the student activities. Other subcommittees are responsible for such special events as all-campus social weekends and intercollegiate conferences.

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

The elected officers of the Non-Resident Student Association run a program of tutorial, athletic, and social events for commuting students which centers around the N.R.S.A. house on Memorial Drive.

Each class at M.I.T. elects a president and executive committee to handle class affairs such as Field Day, Junior Prom and Graduation. Freshmen participate in class government through the Freshman Council, whose members are elected early in the fall.

The Graduate Student Council, comprised of elected representatives from each department, coordinates departmental activities and runs from its office in Walker Memorial a broad program of athletic, social and cultural events for the entire graduate community. The Ashdown House has its own elected group to conduct House government and activities.

Athletics

The purpose of the athletic program at the Institute is to encourage all students to develop interests leading to participation in some form of physical recreation. Instruction is offered in those activities which may be continued in the years following graduation.

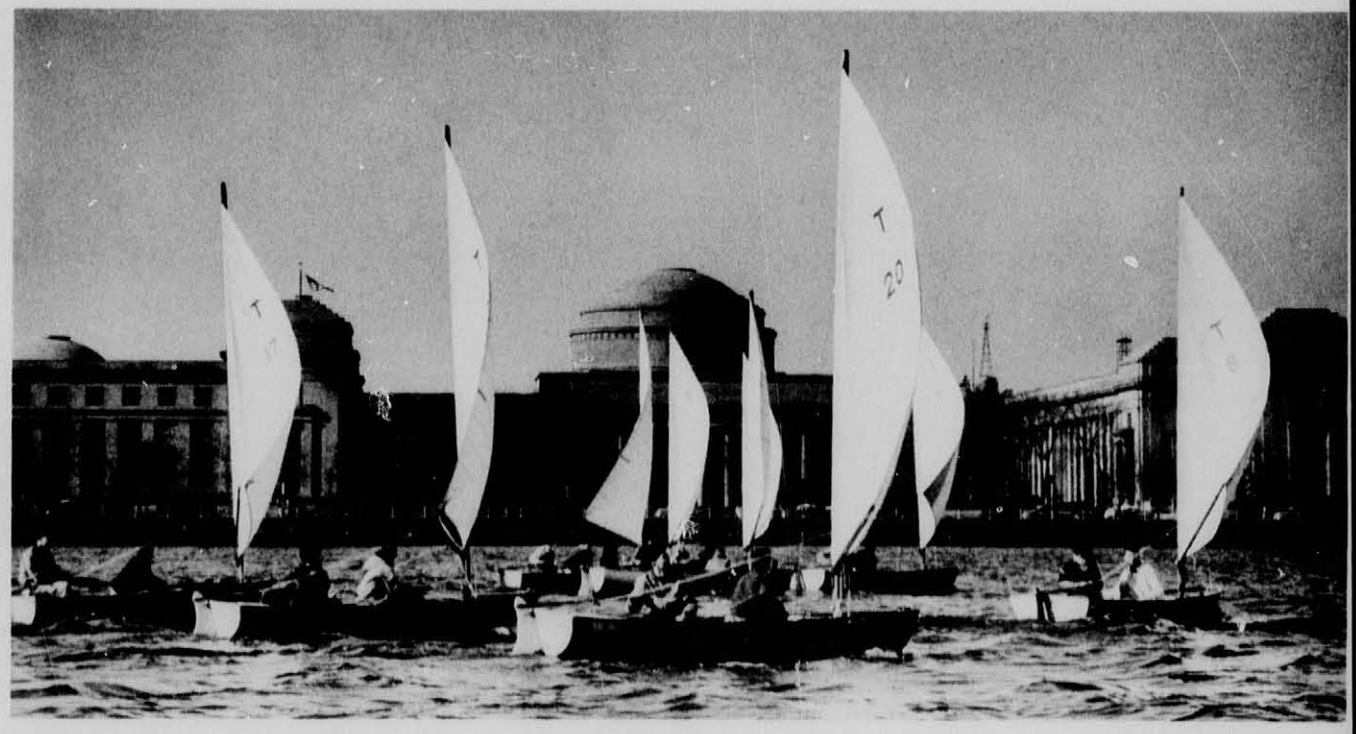
The intercollegiate program last year attracted more than 900 students to competition in 20 sports, while 4,000 undergraduates seeking more informal activities joined intramural and club teams. These figures do not include sailing, which is by far the most popular recreational activity.

M.I.T. has varsity and freshman intercollegiate teams in track and field, cross-country, crew, baseball, skiing, gymnastics, hockey, basketball, fencing, golf, lacrosse, rifle, swimming, tennis, soccer, squash, pistol, sailing, and wrestling. Competition includes many New England colleges and Ivy League schools.

The intramural athletic program is noteworthy; last year over two-thirds of M.I.T. undergraduates participated in over 1,500 intramural contests. There were league competitions in touch football, cross-country, basketball, cycling, softball, volleyball, swimming, track, tennis, table tennis, sailing, badminton, hockey, golf, squash, water polo, wrestling, rifle, water polo, and bowling. Club sports, with intercollegiate competion but less formal organization than varsity teams, include badminton, bicycling, rugby, water polo, cricket, judo, white water, and weightlifting. Undergraduate and graduate students participate in both intramural and club programs.

Excellent facilities for these sports are provided by the du Pont Athletic Center, Rockwell Cage, the du Pont Gymnasium, Briggs Field, the Alumni Swimming Pool, 14 tennis courts, an outdoor skating rink, and the Sailing Pavilion and Pierce Boathouse on the Charles River.

Through the M.I.T. Athletic Association, a unit of student government, undergraduates



share with the Athletic Department the responsibility for planning and operating athletic programs.

Theater

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

Dramashop, the student drama group, presents a varied program under the professional supervision of the Director of Drama and his two assistants: a designer and a technical director. This program includes each year at least two major productions of full-length plays and four workshop productions of one-act plays directed, designed, and acted by students. Dramashop, in conjunction with the Department of Humanities, also sponsors a Celebrity Series including lectures by prominent theatrical people, productions of plays by well-known theater groups, and performances by modern dance and ballet groups. Tech Show is an annual musical comedy written and produced by students. The Gilbert and Sullivan Society presents two Gilbert and Sullivan operettas each year.

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.

Lectures and Seminars

The Lecture Series Committee, an all-student group, brings outstanding and controversial speakers to the campus. Such men as Senator Wayne Morse, Timothy Leary, George Plimpton, Dick Gregory, and Jacques-Yves Cousteau — all have recently delivered talks to the M.I.T. community. In cooperation with the Department of Humanities, the L.S.C. also has presented such entertainment as Stravinsky's *Apollo*, An Evening with Sir John Gielgud and Irene Worth, and Gertrude Stein's *In Circles*. In addition to these programs, L.S.C. is responsible for a highly popular weekend movie series of current and classic movies.

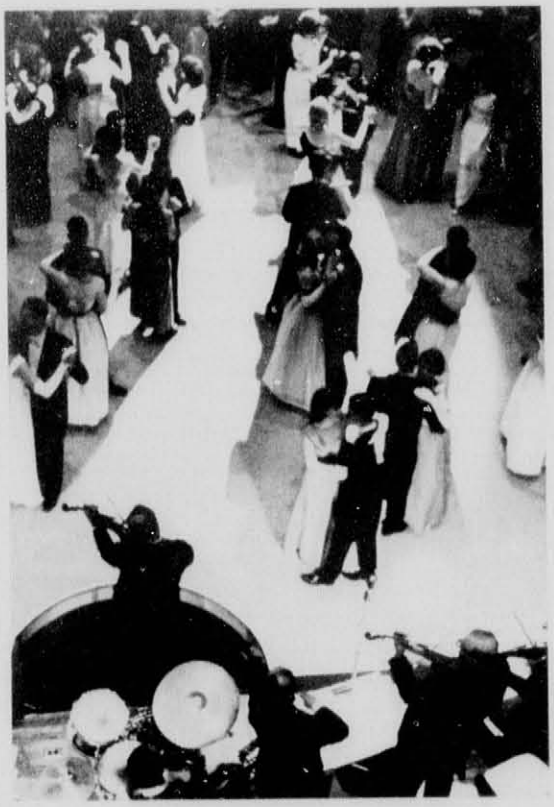
There are excellent professional programs; most departments sponsor series of seminars, many of which attract foreign visitors as well as leading American scientists and engineers. They are supplemented by open lectures on a great variety of current topics.

Music

M.I.T. is a musical community. It has a busy season of musical activities and programs per-











formed by many different musical groups, all of which are open to both undergraduate and graduate students. The Combined Musical Clubs include a Glee Club, Symphony Orchestra, Concert Band, Woodwind and Brass Ensembles, Concert Jazz Band, and a barbershop group — the Logarhythms; there is also a Choral Society, which draws its members from the entire M.I.T. community. These organizations give public concerts on the campus, participate in joint concerts on other northeastern college campuses, and take periodic concert tours throughout the East and Midwest. In 1967 the Glee Club performed Milhaud's *Les Choephores* with the Smith College Choir, and in 1968 its concerts included Honegger's *King David* and Orff's *Carmina Burana;* the Concert Band, which specializes in contemporary compositions written especially for band, gave concerts in the Boston area and toured the eastern United States and Canada; on its 1968 spring tour the Symphony Orchestra appeared at Montclair State College in New Jersey, Denison University in Ohio, Earlham College in Indiana, and George Williams College in Chicago; while the Concert Jazz Band placed in the finals at both the Villanova and Notre Dame Jazz Festivals, appeared on WGBH television, and held a collegiate invitational jazz festival at M.I.T. The Choral Society has three European concert tours to its credit; the last, in 1962, included appearances in London, Cambridge, Paris, Bonn, Berlin and Munich. Here at home they performed Stravinsky's *Symphony of Psalms*, Bartok's *Cantata Profana* and Bruckner's *Mass in E minor* with 63 members of the Boston Symphony Orchestra.

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 various campus organizations.

Religious Organizations

The long-established programs of the several student religious organizations on the campus are focused about the Chapel and the Student Center. Ministers 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 312 Memorial Drive.



CHORAL SOCIETY

DRAMASHOP





OUTING CLUB



TECH SHOW

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.

Student Publications

Student publications at M.I.T. include *The Tech*, student newspaper published twice each week; *Technique*, the senior yearbook; *Tech Engineering News*, monthly student magazine of science and engineering; *Tangent*, literary review; *Innisfree*, journal of inquiry; 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*, and the Technology Community Association prepares an undergraduate guide, *The Social Beaver*.

Technology Community Association

Managed by undergraduates and operated with the help of a permanent staff, T.C.A. conducts a diversified program of year-round services to the M.I.T. community. A handbook for new arrivals on the campus, a theater ticket service, a book exchange, an extensive program of student-taught college level subjects for high school students, duplicating machines for student use, and annual blood donor and charity drives are a few of the activities sponsored by the student members.

Special Interest Groups

There are more than 80 non-athletic 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, the "ham" radio station W1MX, and WTBS (the student-operated FM local broadcasting station).

More than 500 students are actively engaged in social service work in many areas of Greater Boston. Although many of the major projects and over-all coordination is the responsibility of the M.I.T. Social Service Committee, many other student groups such as the Alpha Phi Omega (the national service fraternity) and the Civil Rights Committee have social service projects as one part of their over-all program.

Political groups have traditionally played a significant role in student affairs at M.I.T. Groups such as the Socialist Club, Students for a Democratic Society, Young Americans for Freedom, the Young Republicans, and the Young Democrats have provided means for student involvement and expression in the larger issues of the day. These groups have sponsored teach-ins, guest lecturers, discussion groups and political rallies.

Technology Student Enterprises, Inc., is a new corporation which provides management facilities under which M.I.T. students develop individual and group entrepreneurial efforts.

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.

Numerous nationality clubs sponsor programs which bring foreign students of similar backgrounds together for cultural and social occasions.

The Technology Dames

The wives of M.I.T. students — both undergraduate and graduate — form the Technology Dames. A social and service organization that begins activities in mid-October, the group numbers nearly 400 and sponsors twice-monthly program meetings including International Night and a Spring Fashion Show; weekly bridge, bowling, swimming, and cultural group meetings; a Holiday Dance, neighborhood Newcomer Teas, and a "Graduation" dinner.

Medical Services

The Institute maintains a well equipped Medical Department staffed by specialists, centrally located in the Homberg Memorial Infirmary, a wing of M.I.T.'s main buildings. On the first three floors are doctors' offices and special facilities for minor surgery, ophthalmology, otolaryngology, dental hygiene, X-ray, and laboratory diagnosis. An infirmary with 23 beds and an

General

MEDICAL SERVICES

STUDENT CENTER (*top right*)







operating room are located on the upper floors. Facilities of the Boston and Cambridge hospitals are used in cases involving major operations or complicated procedures, after which students may return to the Infirmary for convalescence.

A Student Health Program has been established by the Institute to underwrite the major portion of the cost of complete medical care for the student and his wife and of hospital and accident expenses for the children of students. While the Program provides outpatient care only when given or authorized by the M.I.T. Medical Department, the hospital and accident insurance coverage offers protection anywhere in the world. Hospital and accident benefits will be paid in addition to any compensation the student may receive from other insurance coverage. Membership in the Student Health Program is required for all students at a cost of $95, which gives coverage from September 1 through August 31. The Student Health Program is optional for the wife of a student and his children. The additional cost of coverage for the wife of a student is $125 per year and for the wife and children is $150 per year.

Initial consultations with a member of the psychiatric service are available to all students and their wives without charge. Short-term psychotherapy, if recommended, will be provided without charge to those in the Student Health Program. Prolonged psychiatric treatment cannot be provided by the Institute psychiatric staff, nor is it underwritten by the Student Health Program. Students requiring such treatment will be referred to private psychiatrists or psychiatric clinics in the area.

Prior to matriculation, every student, undergraduate or graduate, is required to submit 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 Medi-

cal Department promptly for 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 55,000 former students informed of M.I.T. affairs. Chief among its publications is *Technology Review*, a monthly magazine of technology and current affairs of interest to M.I.T. alumni. 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, class reunions, alumni seminars, and conferences in major cities throughout the United States.

Association of M.I.T. Alumnae

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

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.

Lowell Institute School

The Trustee 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 also are offered. The program is designed to bring systematic 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 5-113, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

Lowell Institute Cooperative Broadcasting Council

The Institute is associated with other Boston educational and cultural organizations in the Lowell Institute Cooperative Broadcasting Council. Boston's non-commercial educational stations, WGBH-FM (89.7 mc.), WGBH-TV (Channel 2), and WGBX (Channel 44), are operated with the advice and cooperation of the Council.

M.I.T. participation in programming is coordinated by the Office of Public Relations.

Personal Deposits Office

While students are encouraged to maintain their own checking accounts in commercial banks, the Bursar's Office operates a Personal Deposits Office, Room W20-002, where students may deposit their personal funds in amounts up to $1,000 and draw upon them without charge or interest.

Parking

Parking facilities at M.I.T. are limited. In general, the Institute cannot provide parking for the use of resident students. A limited number of spaces are available for assignment, with the approval of the Dean of Student Affairs, to students with physical handicaps demanding use of an automobile and to a few other undergraduates.

Because demand for student parking far exceeds supply, the matter is under study at the present time. A system of paid parking may be instituted. Students who plan to bring motor vehicles to Cambridge should take careful note of the information regarding pertinent Massachusetts laws which is mailed with their registration material.

Placement

The Institute's Placement Bureau offers employment opportunities to students by arranging on-campus interviews with more than 400 prospective employers, including both company and government representatives. Additional organizations continually notify the Placement Bureau of their available jobs by telephone and letter.

Students planning to obtain advanced degrees will find the reference library, which houses a collection of worldwide graduate school catalogues and financial aid announcements, very useful. Information about summer work is also available here.

The Office of Student Employment (formerly Student Personnel) has recently become a part of the Placement Bureau. Students seeking part-time or temporary work (usually on-campus) will find positions in the dining and residence halls, the libraries, and the various M.I.T. laboratories.

The Alumni Placement Office helps former students obtain positions in all 50 states and in many foreign countries. It also aids industry in selecting men for jobs requiring engineering, management, or scientific experience.

The M.I.T. Press

Since The M.I.T. Press became a wholly independent university press in 1962, it has developed complete facilities for selecting, editing, designing, promoting, and selling its books. More than 500 titles have been published by the Press (almost all are still in print), and currently about 100 hardcover and paperback works are published each year.

One function of the Press is to extend the distribution of M.I.T.'s research and scholarship throughout the world: a substantial proportion of M.I.T. Press books last year were sold in foreign countries. More generally, the range of publication closely parallels the Institute's own range of activity — the Press has issued a balanced list of titles in economics and management, in architecture and urban planning, in science and technology, in international and social studies, and the list is marked by a steadily growing strength in the humanities. Linguistics and computation are areas characterized by a notable depth of coverage. Some of the most widely used and known recent publications are *Beyond the Melting Pot* by Nathan Glazer and Daniel P. Moynihan; *Viet Cong* by Douglas Pike; and *Grooks* by Piet Hein.

Titles also range from the specialized to those of broad general interest, from the topical to those of lasting concern, and from hardcover originals to popular paperback reprints. A recent annual report and a complete descriptive catalogue are available upon request — write The M.I.T. Press, Cambridge, Massachusetts 02142.

The Technology Matrons

Wives of the faculty and senior staff, as well as women members of the faculty and staff, comprise the Technology Matrons. The Matrons usually hold four general gatherings and a number of smaller group meetings for members interested in special activities each year. They sponsor many service projects for the Institute community with special attention to hospitality for foreign and American students, aid to them in seeking housing, and a welcome for new faculty and staff families. The Student Furniture Exchange and English classes for foreign wives are sponsored by Matrons, who also devote many hours to volunteer service projects in the Cambridge area.

General Regulations

Academic Year

The academic work of the Institute is given principally in two 15-week terms, 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. During the Summer Session most classes are held between 8 a.m. and 5 p.m. on weekdays.

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 advisor. Each student's program must be approved by this faculty member, and changes may be made only with his approval. After 13 weeks of a regular term an undergraduate student must petition the Committee on Academic Performance in order to cancel a subject. All first-year students and those second-year students who have not yet made a Course selection have as their advisors Faculty Counselors, 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.

Freshman Grading

Beginning in 1968–69 and continuing for a trial period of four academic years, the grades recorded by the Registrar for freshman students are on a pass-fail basis. At the middle and end of each term, every freshman student shall prepare an evaluation of his work and achievement in each subject and submit it to his instructor on a form provided. The instructor shall in turn write his evaluation. The form shall be delivered to the student and to the student's freshman advisor.

Grade Reports

Grade reports are issued by the Registrar at the end of each term and summer session to all registered students. Parents of first-year students receive term grade reports.

Transcripts

Students may order transcripts of their academic record at the Registrar's Office (Room E19-335) upon presentation of a receipt from the Cashier's Office (Room E19-215) at a cost of $1 per copy.

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 scheduled 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 or the Dean of the Graduate School may permit a student whose term work has been satisfactory to take the next scheduled examination on the subject. The instructor may, if the evidence warrants, issue a final grade without requiring a postponed final examination.

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 design.

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

Undergraduate students who withdraw from the Institute must do so through the office of the Dean of Student Affairs.

Conduct and Discipline

M.I.T. assumes that all students come to the Institute for a serious purpose and expects them to be responsible individuals who demand of themselves high standards of honesty and personal conduct. Therefore, it is M.I.T.'s policy to have as few rules and regulations as are consistent with efficient administration and general welfare.

Fundamental to the principle of independent learning and professional growth is the requirement of honesty and integrity in the performance of academic assignments, both in the classroom and outside, and in the conduct of personal life. Accordingly, M.I.T. holds its students to the highest standards of intellectual integrity and thus the attempt of any student to present as his own any work which he has not performed or to pass any examinations 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 also held as a grave breach of conduct.

M.I.T. has traditionally placed considerable responsibility on undergraduate governing groups to deal with problems in the student community. Each residential unit has its own judicial system which is responsible to an over-all

undergraduate judicial system, which in turn is responsible to the Dean of Student Affairs and the Faculty Committee on Discipline, a standing committee of the Faculty. Minor infractions are handled by that student judicial group which is closest to the problem. Major infractions are handled by the Undergraduate Judicial Committee, the judicial arm of the all-campus student government. Serious infractions which occur on campus and almost all off-campus infractions are considered by the Faculty Committee on Discipline. By custom this Faculty Committee invites one or more students from the undergraduate judicial committees to attend those hearings involving undergraduates.

At the graduate level, no formal student judicial system exists. The majority of cases calling for disciplinary considerations resulting from infractions within the Institute community are handled by the Student's Graduate Registration Officer in consultation with the Dean of the Graduate School and the Dean of Student Affairs. More serious cases including those involving off-campus violations are generally considered by the Faculty Committee on Discipline.

It should be noted that the Institute reserves the right to dismiss at any time a student whom it deems undesirable for any reason. Unethical conduct, wherever it may occur, is held to be sufficient grounds for dismissal.

If a student's infraction involves him both in Institute judicial proceedings and in court proceedings, and if an Institute decision might prejudice his court case, the Institute will hold its decision in abeyance until after the court proceedings have been concluded.

The office of the Dean of Student Affairs is responsible for all matters pertaining to general student welfare.

Official Notices

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

Motor Vehicles

All motor vehicles operated by students must be registered each term with the Campus Patrol within 30 days after Registration Day. Students should also note the requirement that out-of-state automobiles operated by M.I.T. students must be registered with the Cambridge Police Department, and students should consult the Massachusetts Registry of Motor Vehicles to verify that their registration and operators' licenses are valid in the Commonwealth.

Fees

The tuition for all regular full-time students[1], including academic and graduate student staff, in the first and second terms is $1,075 per term. The tuition for graduate fellows, trainees, and academic staff in the Summer Session is $720. (Special tuition rates apply to other students in the Summer Session; these are published each year in the Summer Session Catalogue, available about March 25.)

Special Students (including M.I.T. sponsored-research staff), and regular students other than fellows and academic and graduate student staff, who are permitted by their Registration Officers or Faculty Counselors to take only a few subjects in the first or second term, will be charged at the rate of $34 per unit taken either for credit or not for credit. Except for thesis, the minimum tuition is $200 for regular students and for Special Students who are employed by the Institute or who are dependents of employees or students and $400 for other Special Students. The maximum tuition is $1,075 per term.

The tuition fee for thesis research for the Bachelor's degree is $34 per unit credit in either regular term, with a minimum of $100 and a maximum of $1,075. If other subjects are taken in addition to thesis, the minimum tuition fee for thesis applies to the thesis portion of the registration and the minimum of $200 applies to the total tuition for the term.

Any graduate student making progress on his thesis is expected to register for thesis and is considered a full-time student. If a graduate student requires only part of a term to complete his thesis, he must pay, initially, full tuition for the term; but if he was registered in the immediately preceding term, regular or summer, his tuition for thesis will be adjusted after delivery of the completed document on the basis of a charge of $105 per week from the starting date of the term, with a minimum of $105 for the Bachelor in Architecture, Master's or Engineer

[1] A regular student is one who is enrolled as an applicant for an academic degree; others are Special Students. Special Students are not permitted to register for thesis.

degree and $210 for the doctor's degree. If the immediately preceding term was the summer term and if the graduate student was not registered for thesis in that summer term, but was registered in the previous regular term, the minimum tuition for thesis is $525. A student who continues to hold a fellowship, traineeship, or academic or graduate staff appointment for the remainder of the term after delivery of the thesis continues to be regarded as a full-time student and his tuition will not be adjusted.

Upon recommendation of a department, the Dean of the Graduate School in the case of a graduate student or the Dean of Student Affairs in the case of an undergraduate student may set a special tuition rate in unusual circumstances.

The tuition fee for a student taking cooperative work in Electrical Engineering (Course VI-A) for the 12-month period, July 1 to June 30, is $2,150, payable $1,075 on or before August 1 and $1,075 on the date when the second term tuition is normally due. 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) pay a tuition fee of $2,150 for the period extending from the end of the spring term of their sophomore year to the beginning of the fall term of their senior year. This fee is payable in two parts — $1,075 on or before August 1 of the first summer and $1,075 on the date when second term tuition is normally due. This tuition fee covers registration by the student for regular and summer terms spent at the Institute and for time spent at the plant. Upon recommendation of the Department, a special tuition rate may be set for an unusual case.

For the School of Chemical Engineering Practice (Course X-A) for the period September through January or February through June, the tuition fee is $1,075.

Tuition Refunds

Students withdrawing during the first or second term are charged one-tenth of the stated tuition for the term for each week from the starting date of the term. 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 cancellation of a subject or withdrawal from the Institute is effected.

Institute House Rentals and Meals

All term rentals, both for Ashdown House and all undergraduate Houses, and all fees for commons meals are to be paid to the Bursar at the beginning of each term.

Application Fee

A citizen of the United States or of Canada, or a foreign student studying at a U.S. or Canadian institution, who files a final application for admission as a regular undergraduate or graduate student, or as a beginning special student, is required to pay a $10 application fee. This fee is not required of a student who applies for readmission as a candidate for the same degree, or, in the case of a graduate student, for a higher degree after a lapse of less than two years. Foreign students filing final application forms from their home countries are not required to pay the $10 application fee.

Other Fees

If, in complying with the doctoral degree language requirement, a graduate student requests a written examination in French, German, Russian, or Spanish at an unscheduled time, he is required to submit with his application a receipt from the Bursar indicating that he has paid a special fee of $30 for this purpose. Any student who fails to appear for a predoctoral language examination is subject to a fine of $10. The fee for the Student Health Program, which is required of all regular full-time students, is $47.50 per half-year in the case of a single student; $110 for a student and wife; and $122.50 for a student, his wife, and children.

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 Laboratory 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 taking MILITARY SCIENCE or AIR SCIENCE requiring uniforms.
2. All undergraduate and graduate students taking subjects requiring supplies from the Office of 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.

Payments

All payments are to be made to the Bursar, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, by the time specified in the registration instructions issued prior to the opening of each term. (For convenience, checks may be made payable to "Bursar, M.I.T.") Many students choose to make their payments under the budget plan described below.

Deferred Payment Plan for Fees

A student or his parents may arrange with the Bursar, by mail or in person, to pay fees in eight (or less) equal 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 on the Bursar's Registration Form included with each student's registration material, in the section captioned "Financial Plan."

These financial arrangements will be confirmed to the student by a "Fees Receivable Statement" shortly after the start of each term. These statements will be continued monthly as long as there is a balance in his account.

An example of a maximum arrangement for the 1968–69 fees for men students is shown below. Note that this covers certain fees only and does not represent the total expense for an academic year.

EXAMPLE OF DEFERRED PAYMENT PLAN

Fees		*Payments*		
Tuition	$2,150.00	September	18	$ 415.25
Average dormitory rent	440.00	November	1	415.00
		December	2	415.00
Commons meals	519.75	January	2	415.00
Medical insurance	95.00[1]	January	29	400.50
Laboratory and/or military equipment deposit	50.00	March	3	398.00
		April	1	398.00
		May	1	398.00
	$3,254.75			$3,254.75

[1] Covers a 12-month period for a single person.

In the event of the termination of the student during the term, all fees due must be paid by special arrangement with the Bursar.

Financial Aids

M.I.T. has a broad program of financial assistance for both undergraduate and graduate students. The Deferred Payment Plan (see above), Installment Credit Plan, and Student Employment are available to all graduates and undergraduates — with the exceptions stated.

Scholarship and loan awards are provided to undergraduates with financial need, as determined through analysis of the Parents' Confidential Statement of finances following guidelines established by the College Scholarship Service. Further information on scholarship and loan assistance will be found in Section 2 of this Catalogue, under Costs.

Financial assistance programs available to graduate students include scholarships, fellowships, loans, and teaching and research appointments; further descriptions will be found in Section 3 of this Catalogue.

Installment Credit Plan for Tuition

An optional Installment Credit Plan is available to all degree candidates, including entering freshmen, who are citizens of the United States, who are in satisfactory academic standing, and who have no other current loan from the Institute. Under this plan, yearly tuition costs in excess of $1,000 may be met by applying to the Director of Student Aid. Thus a student may use the Credit Plan to obtain a maximum four-year credit of $4,600. 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 Student Aid Center.

Student Employment

The Office of Student Employment 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 in the freshman year does not usually exceed $250 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 EDUCATION: *A Tradition of Excellence* 2.



The Massachusetts Institute of Technology maintains a tradition of excellence in preparing its undergraduates for creative graduate work or professional activity. Because standards of admission are high, the educational program is set at a level which offers to students the opportunity to acquire deep understanding of basic scientific principles and to develop habits of thought characteristic of leaders in science and engineering.

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 application of science through engineering, the study of science for its own sake, and the awareness of the impact of engineering and science upon our physical environment and upon our conduct of industry, government, and society. An integrated program of studies in the humanities and social sciences extends through the undergraduate years, developing powers of judgment and taste and strengthening the student's ability both to meet the basic requirements of his profession and to assume effectively wide responsibilities in public and private life.

Each Course curriculum leading to a Bachelor's degree consists of two major divisions: the General Institute Requirements and a Departmental Program.

The General Institute Requirements consist in part of certain specific subjects in science, and in part of science distribution subjects, a project-type laboratory, and humanities and social science offerings, among which each student may exercise a considerable range of individual choice.

Each Departmental Program consists, in part, of a grouping of subjects in the areas of professional interest to the Course or Courses represented by that particular department and, in part, of additional opportunities for the student to take subjects of his choice. By Institute rule, considerable time for electives is available to every student throughout the four years.

A student can use these elective opportunities to follow special interests, or to deepen and broaden his educational background. Alterna-

tively, he can use his elective time to prepare for advanced study in some professional field, such as medicine or law; for graduate study in some area in which M.I.T. gives no undergraduate degree, such as city and regional planning, meteorology, or oceanography; or for advanced study in a field which is interdisciplinary, such as astrophysics, communication science, or space science and technology.

The pattern for the Bachelor's degree program provides a basis for education in rapidly developing and growing fields of knowledge; it is excellent for those who will follow professions in architecture, engineering, science, economics, political science, or management; and it offers a sound foundation for careers partly or wholly unrelated to these professions.

The Undergraduate Programs

The undergraduate subjects are planned and coordinated to give each student an understanding of scientific and technological knowledge through a variety of alternative paths. Each subject attempts to give undergraduates an opportunity to explore the intrinsic intellectual excitement of its contents; to stimulate an aggressive rather than a passive involvement in the subject matter; and to provide motivation for creative work and continuing self-education.

An undergraduate at M.I.T. may choose his major field of study from among 24 Courses; a complete list of undergraduate Courses and degrees is given in Section 1 of this Catalogue. The program for the Bachelor of Science degree normally requires four years of full-time study.

To complete work for a Bachelor's degree in any Course, each student must fulfill the General Institute Requirements and must complete the Departmental Program specified by that Course. However, each student in every Course has considerable freedom in planning his academic program. Within limits imposed by the prerequisites, each student can schedule his own sequence of subjects in consultation with his Faculty Counselor. Flexibility in the choice of electives and subjects fulfilling the Science Distribution and Laboratory Requirements and, for superior students, the opportunity to take examinations for advanced standing, all permit a student to design a program around his own particular background, interests, abilities, and future goals.

Furthermore, in some cases, a student may substitute other subjects for certain of those specified by his Course. To assure that such substitutions be well thought out and not haphazardly chosen, a student must obtain permission from his Faculty Counselor, during his junior year, to embark on a program involving a "major departure" from an approved curriculum. (The term "major departure" is understood to signify substitutions not-in-kind for more than one required subject, or substitutions of any sort for more than two required subjects.)

Each undergraduate Course offers the degree of Bachelor of Science with the field of the degree specified, as for instance Bachelor of Science in Electrical Engineering. Some departments also offer in addition an undesignated degree of Bachelor of Science. The purpose of this arrangement is to provide further flexibility by making available curricula which may cross disciplinary and departmental lines. While the undergraduate curriculum for an undesignated Bachelor of Science degree, as listed by a Department, may have its own unique features, each individual program must be laid out in consultation with a departmental representative to assure that it is meaningful in structure and challenging in content.

In the first year most students concentrate on a program centered around mathematics, physics, chemistry, and humanities.

During the second year studies are ordinarily continued with subjects meeting the Science Distribution, Laboratory, and humanities requirements and with 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 4 through 8 of this Catalogue, where descriptions of the departments in each school are arranged alphabetically by school. The General Institute Requirements are set forth in the next few pages, and the Departmental Programs are listed by each department.

Selection of Courses

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 the various Courses avail-

able 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. They also are urged to select electives which will help them in deciding about their future careers. For many students this thoughtful consideration of available possibilities 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 creative 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 challenge and rewarding satisfaction 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 time for others to explore their interests, assess their abilities, and choose a Course which satisfies both.

Each student entering M.I.T. is assigned a Counselor, a member of the Faculty who assists the student in designing an effective program of study appropriate to his interests and aspirations. The selection of electives is one of the important problems on which each student should work in detail with his Counselor. For example, if a student has not decided on a specific Course, he is advised to register for electives and Science Distribution Subjects which are relevant to the Courses he is considering. It is important that these subjects be selected with care because each department has different recommendations for Science Distribution Subjects, and an inappropriate choice may delay graduation in some instances because of scheduling difficulties, or it may decrease elective freedom in the third and fourth years. Counselors can help students utilize most effectively the elective freedoms which are assured in all M.I.T. curricula.

Premedical Education

In recent years an increasing number of students has entered medical school upon graduation from M.I.T. Specific medical school entrance requirements can be met in almost any of the Institute's Courses by proper selection of electives. The broad premedical programs that result fully meet the specifications of the Association of American Medical Colleges.

A Premedical Advisory Committee — whose members are directly involved in medical practice, related medical research and in student counseling — provides information to students interested in medical careers. Each student is encouraged to take advantage of the flexibility and diversity of the available academic programs. The Program is administered for the Committee by Professor Emily L. Wick, Associate Dean of Student Affairs, who maintains liaison among the student, his Faculty Counselor, and the Premedical Advisors.

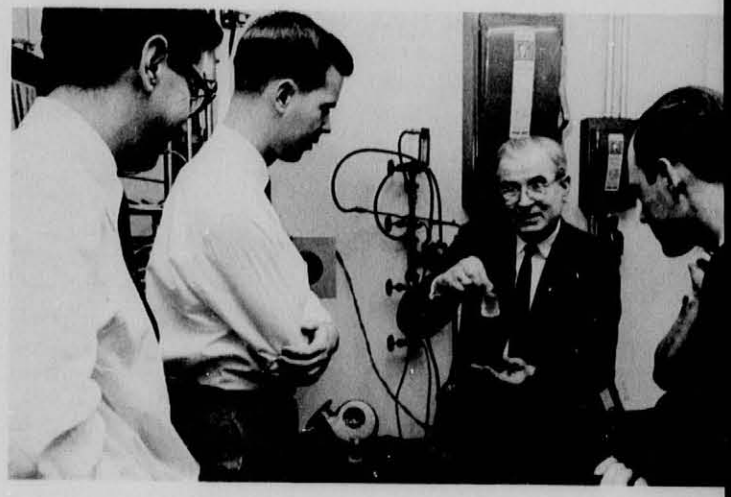
Engineering and Living Systems

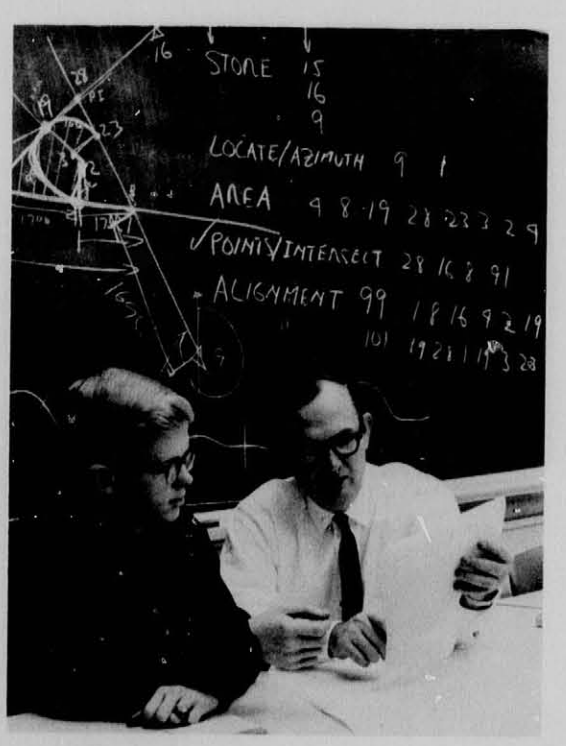
An area of study which is of increasing interest to undergraduate and graduate students alike lies at the interface between the engineering and life and health sciences. Investigations on such varied topics as the physical properties of blood, mechanisms of sensory perception, and the control of prosthetic limbs, to name only a few, involve faculty and students from most of the engineering departments. Much of this research is carried out in interdepartmental laboratories, in collaboration with workers from medical centers in the Boston area. The undergraduate wishing to explore this developing area will have ample opportunity within his regular departmental major through elective subjects, special laboratory projects, and the senior thesis. These studies should be of special interest to students who are enrolled in a premedical curriculum. Graduate study in Engineering and Living Systems is open to students with appropriate undergraduate background in either the engineering or biological sciences. The Steering Committee on Engineering and Living Systems serves as an advisory body which can assist students in setting up interdepartmental programs. The Chairman of this Committee is Murray Eden, Professor of Electrical Engineering.

Prelaw Education

A small number of students enter law schools from M.I.T. each year. Although law schools do not prescribe particular undergraduate prep-






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aration as a condition of admission, a showing of thorough learning in some area of study, such as economics, science, government, or mathematics, is viewed favorably. While a typical M.I.T. education fits well with the preferences of the leading schools, students may wish to consult Stanley M. Jacks, the Institute's Prelaw Advisor, regarding preparation for law school. He maintains a list of accredited law schools, the dates of the law school admission test, and other information pertaining to the study of law.

Science and Mathematics Teaching

Students who are interested in careers in teaching high school science or mathematics may arrange special 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 Robert E. MacMaster.

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 Dean 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 Master's thesis. A student wishing to pursue this program should submit a petition approved by the undergraduate Faculty Counselor and the graduate Registration Officer. The requirements for the various honors and other five-year Courses leading to the S.B. and S.M. degrees are specified under the appropriate department statements.

Program for a Second Bachelor's Degree

A student may work for a second Bachelor's degree to be received subsequent to or concurrent with the Bachelor's degree in his primary Course. The requirements for the second degree are the completion of a program of at least 90 units in addition to subjects used for the first degree, resulting in a total of at least 450 units for two Bachelor's degrees. Before starting on this program the student should submit a petition which lists the specific subjects for the second degree and which has been approved by the Faculty Counselors in the departments concerned. The student stays registered in his primary Course until the degree is received in this Course. Another petition should be submitted if there are any changes in the program for the second degree.

Subject Registration

It is not usually necessary to restrict the number of students admitted to a subject. If an unexpectedly large number apply 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 regular term. Each subject is listed with three credit numbers, showing in sequence the units allotted to: class; laboratory, design, or field work; and preparation. Each unit represents 15 hours of work per term. The total unit credit for a subject is obtained by adding together all the units shown. The typical undergraduate student load, based on a four-year program, is 45 to 51 units per term. However, if approved by his Faculty Counselor, a student may follow a program leading to an S.B. degree in either more or less than eight terms.

Degree Requirements

To be recommended for the degree of Bachelor of Science, 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 the rules and regulations of the Faculty, including the General Institute Requirements and the Departmental Program of the Course in which his degree is to be awarded. Departures from the Departmental Programs are permitted with the consent of the Faculty Counselor. The Departmental Program and the total number of units required are shown for each Course in Sections 4, 5, 6, 7, and 8 of this Catalogue.

The General Institute Requirements include:

1. Completion of the science subjects CHEMISTRY (5.01), CALCULUS (18.01 and 18.02), and PHYSICS I and II (8.01 and 8.02).

2. Completion of the requirements in humanities and social sciences, described on pages 50–55 of this Catalogue.

3. Completion of the Science Distribution Requirement, described on pages 48–49 of this Catalogue.

4. Completion of the Laboratory Requirement, described on page 49 of this Catalogue.

5. Completion of the physical education requirements described on pages 49–50 of this Catalogue.

In summary, to be recommended for the degree of Bachelor of Science, a student must have satisfactorily completed the following units:

		Total Units
GENERAL INSTITUTE REQUIREMENTS		
Specific Science Subjects:		
CHEMISTRY (5.01)	12	
PHYSICS I AND II (8.01 and 8.02)	24	
CALCULUS (18.01 and 18.02)	24	
Humanities:		
First- and second-year humanities	36	
Third- and fourth-year humanities	32	
		128
Science Distribution and Laboratory Subjects:		
Science Distribution Subjects (in at least three fields)		**36**[1]
Laboratory Subjects		**12**[1]
DEPARTMENTAL PROGRAM		
As specified for each Course, a minimum of		**184**[2,3]
Total units required for the S.B. degree, at least		**360**[4]

[1] Each department may specify some of the Science Distribution and Laboratory Subjects.
[2] Departments may require up to 209 units (leading to a total of 385 units) for graduation.
[3] Departmental Programs include at least 36 units of electives, usually more.
[4] This total does not include advanced Army R.O.T.C., if elected.

The First-Year Program

For students entering M.I.T. with only the preparation implied by the entrance requirements, the first-year program commonly contains electives and required subjects in mathematics, physics, chemistry, and humanities. These subjects provide an appropriate preparation for all the Courses of undergraduate study offered at M.I.T.

One possible schedule for the two terms of the first year is as follows:

First Term

		Units
5.01	CHEMISTRY	5 0 7
8.01	PHYSICS I	5 0 7
18.01	CALCULUS	4 0 8
	HUMANITIES (*see page 50*)	3 0 6
		45

Second Term

8.02	PHYSICS II	5 0 7
18.02	CALCULUS	4 0 8
	HUMANITIES (*see page 50*)	3 0 6
	Elective	12
		45

This schedule is by no means unique. Some students may find it appropriate to their specific backgrounds to postpone one of the major scientific subjects [such as PHYSICS I (8.01) or CHEMISTRY (5.01) until the second term of the year. They can use the time thus made available to explore elective opportunities or to improve their high school preparation by registering in appropriate subjects. To this end, another possible schedule is:

First Term

		Units
5.01	CHEMISTRY	5 0 7
18.01	CALCULUS	4 0 8
	HUMANITIES (*see page 50*)	3 0 6
		33
	Additional elective subjects if desired	6 to 12
		39 to 45

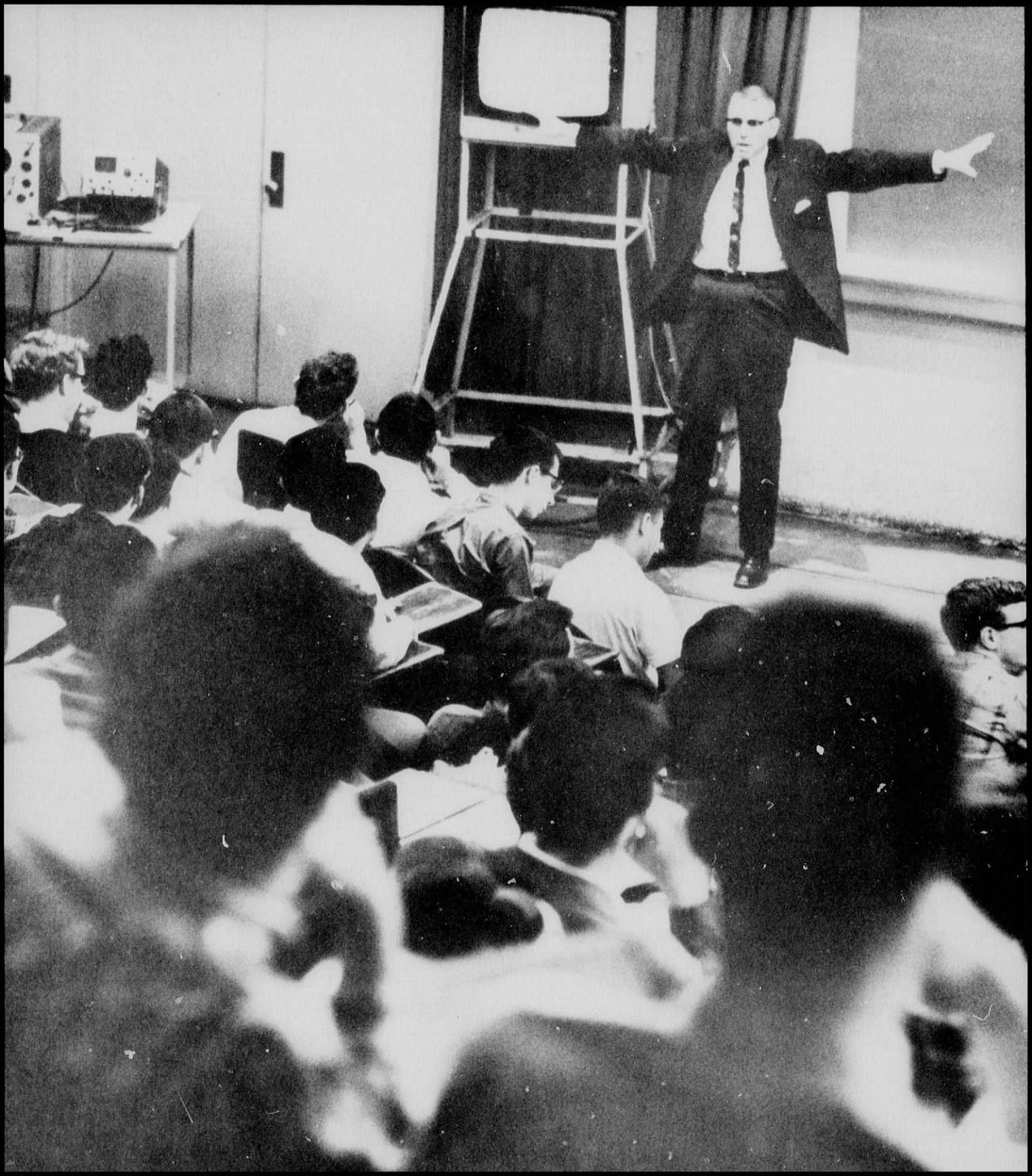
Second Term

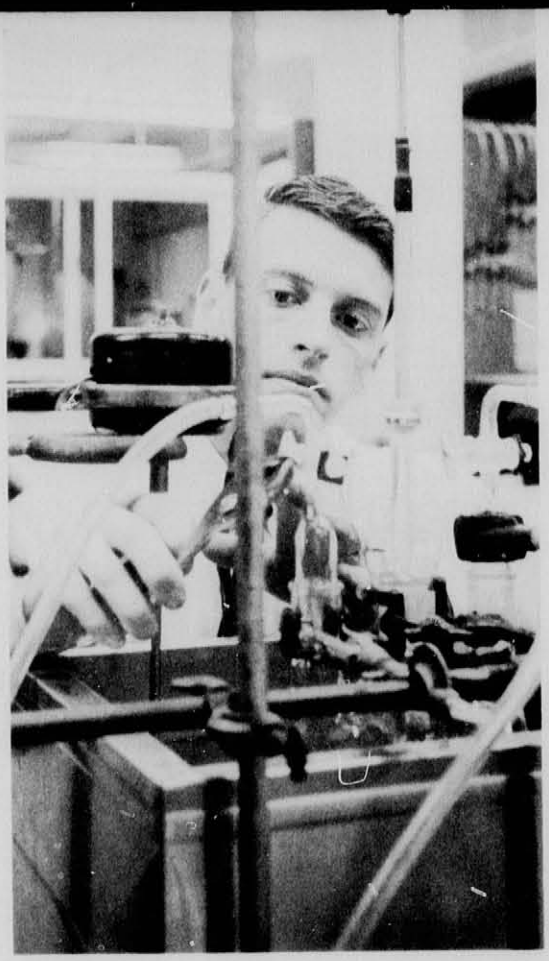
8.01	PHYSICS I	5 0 7
18.02	CALCULUS	4 0 8
	HUMANITIES (*see page 50*)	3 0 6
	Elective	12
		45

Variations in the First-Year Program

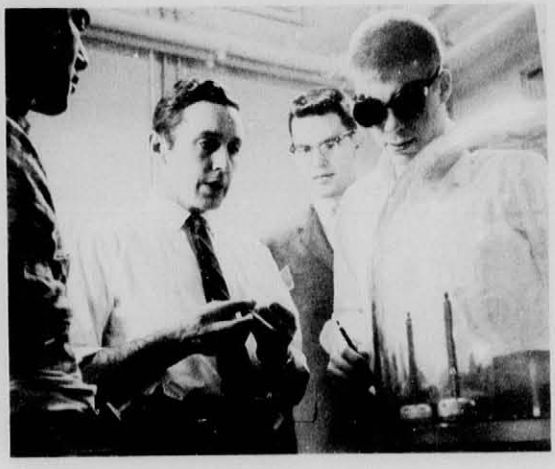
There are several other possible first-year programs. Entering students with degree credit in one or more of the first-year subjects may substitute more advanced subjects in the same areas or may use the time thus made available for electives or science distribution subjects. If the credit is in the appropriate prerequisites, the student may begin elementary work in a professional field by taking subjects which would usually occur in his second or third year. The procedures by which degree credit at entrance is earned are described in the section of this Catalogue dealing with admission to the Institute (page 65).

For freshmen with strong records in the first term, some subjects in the humanities and social sciences normally open only to upperclassmen are available during the second term.









Some students of outstanding ability prefer to avail themselves of the opportunities to accelerate their programs through the Advanced Standing Examinations described elsewhere in this Catalogue. However, neither regular language subjects paralleling those completed in secondary school nor Undergraduate Seminars can be completed through Advanced Standing Examinations.

As mentioned previously, 45 to 51 units per term is considered by the Faculty to be the typical student load. A heavier or lighter program can be carried by a student with the approval of his Faculty Counselor. No change in tuition fees is made either for carrying an extra subject or for omitting a subject in any term.

The First-Year Electives

The first-year electives may be chosen from subjects expressly designed for this purpose (including the Undergraduate Seminars), from upperclass electives without prerequisites, or from any other subjects offered by the Institute for which the student either has the prerequisites or has sufficient preparation to justify the waiving of the prerequisites by the instructor in charge.

Elective time in the freshman year represents an opportunity to explore potential fields of interest. Subjects with minimal prerequisites or no previous experience required exist in all departments, and each student should assess his own inclination and ability before deciding on specific subjects. In previous years, freshmen have chosen a wide range of basic subjects as electives, the most common of which are listed below.

Examples of Electives Suitable for Freshmen

1.40	INTRODUCTION TO ELECTRON MICROSCOPY
1.401	[1]PHYSICS OF MATERIALS
2.101	COMPUTER MODELS OF PHYSICAL AND ENGINEERING SYSTEMS I
2.701J	ARCHITECTURAL COMMUNICATION
2.711	ENGINEERING GEOMETRY
2.723	ELEMENTARY NOMOGRAPHY
3.09	[1]STRUCTURE AND PROPERTIES OF SOLIDS
4.011	[1]GRAPHICS LABORATORY I
4.701J	ARCHITECTURAL COMMUNICATION
5.20	LABORATORY PROBLEMS IN CHEMISTRY
6.251	DIGITAL COMPUTER PROGRAMMING SYSTEMS*
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION
7.00	[2]PERSPECTIVES IN LIFE SCIENCE
9.00	INTRODUCTORY PSYCHOLOGY
12.201	[1]EARTH SCIENCE
12.202	[2]ASTRONOMY
14.01	ECONOMIC PRINCIPLES I
16.70	[1]AIRCRAFT AND SPACECRAFT DESIGN
16.81	[1]FLIGHT VEHICLES
16.82	[2]AEROSPACE ENGINEERING
18.00	[1]ELEMENTARY NUMBER THEORY

19.003	[2]ELEMENTARY METEOROLOGY I
21.091	[1]PHILOSOPHY AND SCIENTIFIC METHOD
21.094	[1]INTRODUCTION TO CONTEMPORARY PHILOSOPHY
21.096	THE WRITING OF PROSE
21.81	MATERIALS OF MUSIC
21.82	INTRODUCTION TO MUSIC
23.11	ELEMENTARY GERMAN
23.91	ELEMENTARY RUSSIAN
SEM11	UNDERGRADUATE SEMINAR
SEM12	UNDERGRADUATE SEMINAR

*Previous programming experience required.
[1] Offered first term only.
[2] Offered second term only.

Other subjects, including those offered by the Department of Modern Languages and Linguistics, are open to qualified freshmen. Students who wish to continue study of a language begun elsewhere may consult the instructors in the Department of Modern Languages and Linguistics concerning the appropriate subjects to be taken.

The R.O.T.C. programs, described in the Catalogue, are normally begun as electives in the freshman year.

The Undergraduate Seminars (SEM 11 and SEM 12) differ from other electives in that they are designed to allow students to work in small groups in close association with faculty members. Less formally organized than customary classroom or laboratory subjects, they offer an opportunity for study with a high degree of individual responsibility and freedom in planning and executing a selected program. The seminars cover a wide range of topics and involve many different types of study. A list of those available is supplied to first-year students during the summer. Enrollment may be limited where demand exceeds facilities.

The Science Distribution Requirement

The Science Distribution Requirement of 36 units is met by taking subjects especially designed for this purpose. Available subjects are listed below. To fulfill the requirement, students must study subjects in at least three different departments and in at least three different fields; the combination of subjects chosen must be approved by the student's Faculty Counselor. Science Distribution Subjects are normally taken in the second year, but students who have the proper prerequisites may take them in the first year. The prerequisites for these subjects are given with the descriptions.

1.00	INFORMATION SYSTEMS (3–3–6)
1.01	ENGINEERING MECHANICS (4–0–8)
1.02	ENGINEERING MATERIALS (3–3–6)
1.03	ENGINEERING ANALYSIS (4–0–8)
1.08	GEOTECHNOLOGY (3–3–6)
2.00	INTRODUCTION TO ENGINEERING SYSTEMS (3–3–6)
2.01	MECHANICS OF SOLIDS (4–0–8)
2.02	INTRODUCTION TO SYSTEM DYNAMICS (3–1–8)
2.403	THERMODYNAMICS (4–0–8)
2.42	ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS (4–0–8)
2.901J	POLYMER MATERIALS SCIENCE (3–0–9)
3.00	THERMODYNAMICS OF MATERIALS (4–0–8)
3.11	MECHANICS OF MATERIALS (4–0–8)
3.141	SCIENCE OF MATERIALS (4–3–5)
4.30	STRUCTURES I (3–3–6)
5.41	ORGANIC CHEMISTRY I (4–0–8)
5.60	CHEMICAL THERMODYNAMICS (4–0–8)
5.63	PHYSICAL CHEMISTRY (4–0–8)
6.001	ELEMENTS, SYSTEMS, AND COMPUTATION I (4–0–8)
6.01	INTRODUCTORY CIRCUIT THEORY (4–0–8)
6.013	INTRODUCTORY CIRCUIT THEORY (4–0–8)
6.14	ELECTRONIC NETWORKS AND DEVICES (4–2–6)
7.01	GENERAL BIOLOGY (4–0–8)
8.03T	PHYSICS III (5–0–7)
10.12	STAGED CASCADES IN CHEMICAL PROCESSING (3–3–6)
10.13T	CHEMICAL ENGINEERING THERMODYNAMICS (4–0–8)
10.641J	POLYMER MATERIALS SCIENCE (3–0–9)
12.223	CRYSTALLOGRAPHY (2–2–2)
12.224	THEORETICAL MINERALOGY (2–0–4)
12.231	GEOLOGY I (3–4–5)
12.612	EARTH AND SOLAR SYSTEM (3–0–9)
12.811	PHYSICAL OCEANOGRAPHY (3–0–9)
13.63	HYDROSPACE VEHICLES AND THEIR USE (3–0–9)
16.001	THERMODYNAMICS AND STATISTICAL MECHANICS (4–2–6)
16.01	DYNAMICS (4–2–6)
16.09	FIELDS IN CONTINUOUS MEDIA (4–2–6)
16.20	SOLID MECHANICS I (4–2–6)
18.034	DIFFERENTIAL EQUATIONS (3–0–9)
18.10	APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES (3–0–9)
19.83	PHYSICAL OCEANOGRAPHY (3–0–9)
22.01	INTRODUCTION TO NUCLEAR REACTOR ENGINEERING (3–0–9)

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

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

Most Departmental Programs occupy 48 units in the second year. In many cases, subjects required by a department are also on the list of

Science Distribution or Laboratory Subjects. Thus students following a particular Departmental Program may satisfy simultaneously part or all of the Science Distribution or Laboratory Requirements. This provides additional flexibility in the planning of a second-year program.

The Laboratory Requirement

The Laboratory Requirement of 12 units may be met by enrolling in one or two laboratory subjects expressly designed for this purpose. Available subjects are listed below. The Laboratory Requirement is normally fulfilled in the first two years, but some students may choose to postpone it. The Laboratory Subjects must be approved by the student's Faculty Counselor.

1.10	CIVIL ENGINEERING LABORATORY (0–6–6)
2.654	PHYSICAL MEASUREMENT AND ANALYSIS (2–6–4)
2.67	DESIGN AND EXPERIMENT (2–6–4)
2.672	EXPERIMENTAL ENGINEERING I (1–3–2)
2.673	EXPERIMENTAL ENGINEERING II (0–4–2)
2.86	MANUFACTURING PROJECT LABORATORY (2–3–1)
2.861	[1]ENGINEERING DESIGN AND MANUFACTURE (4–4–4)
3.04	MATERIALS RESEARCH LABORATORY (1–3–2)
3.05	MATERIALS RESEARCH LABORATORY (2–6–4)
5.20	LABORATORY PROBLEMS IN CHEMISTRY (1–3–2)
5.21	LABORATORY PROBLEMS IN CHEMISTRY (1–6–5)
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION (2–8–2)
5.613	PHYSICAL CHEMISTRY LABORATORY I (0–4–2)
5.623	PHYSICAL CHEMISTRY LABORATORY II (0–4–2)
6.272	DIGITAL SYSTEMS PROJECT LABORATORY (2–8–2)
6.70	ELECTRONIC COMPONENTS AND MEASUREMENTS (1–4–1)
6.71	ELECTRONIC CIRCUITS AND SIGNALS LABORATORY (1–4–1)
6.711	DIGITAL SYSTEMS PROJECT LABORATORY (2–8–2)
6.712	BIOELECTRONICS PROJECT LABORATORY (2–8–2)
6.714	ELECTRONIC LIGHT MEASUREMENTS PROJECT LABORATORY (2–8–2)
6.715	POWER SYSTEMS PROJECT LABORATORY (2–8–2)
6.716	PARTICLE OPTICS PROJECT LABORATORY (2–8–2)
6.717	AUDIO FREQUENCY COMMUNICATIONS PROJECT LABORATORY (2–8–2)
6.718	VHF CIRCUITS PROJECT LABORATORY (2–8–2)
6.719	SEMICONDUCTOR DEVICES AND CIRCUITS PROJECT LABORATORY (2–8–2)
7.02	GENERAL BIOLOGY LABORATORY (1–8–3)
8.11T	PHYSICS PROJECT LABORATORY I (1–6–5)
8.12T	PHYSICS PROJECT LABORATORY II (1–6–5)
8.13T	EXPERIMENTAL ATOMIC PHYSICS I (0–6–6)
9.50	RESEARCH IN PSYCHOLOGY (Arr. — minimum 6 units)
10.91	EXPERIMENTAL RESEARCH PROBLEM (Arr. — minimum 6 units)
15.571	FEEDBACK DYNAMICS LABORATORY (2–6–4)
16.62	EXPERIMENTAL PROJECTS (2–6–4)
20.02	NUTRITION AND FOOD SCIENCE PROJECTS LABORATORY (1–8–3)

[1] Students taking 2.861 (12 units) receive 6 units of laboratory credit.

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

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

The Physical Education Requirement

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 each male student must have compiled at least 8 points of athletic credit. These points may be acquired by participating in a physical education class (2 points per quarter) or by membership on one of the 20 freshman or varsity teams (2 points for fall or spring sports, 4 points for winter sports).

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

Physical education classes for the year are divided into four quarters, with these activities:
First quarter — September to mid-November: archery, development class, golf, gymnastics, touch football, lacrosse, sailing, beginning swimming, pistol, beginning tennis, and intermediate tennis.
Second quarter — mid-November through January: badminton, basketball, bowling, development class, fencing, judo, scuba diving, skating, skiing, squash, rifle, beginning swimming, intermediate swimming, and Red Cross senior life saving.

Third quarter — February through March: bowling, development class, diving, fencing, judo, skating, skiing, squash, beginning swimming, volleyball, pistol, and Red Cross senior life saving and instruction.

Fourth quarter — April through May: archery, development class, beginning golf, intermediate golf, sailing, soccer, softball, beginning swimming, beginning tennis, intermediate tennis, rifle, and Red Cross instructors' program (continued).

Upon entering M.I.T. each male student must submit a record of a medical examination and take a swimming and physical fitness test. Students who fail the swimming test are required to take beginning swimming, and students who fail the fitness test are recommended for the development class. If the medical examination indicates any disability which might limit physical activities, the athletic requirements may be modified.

Although there are no specific requirements for women students, facilities are provided for many activities of their choice, and women may participate in many physical education classes.

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 study 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 one subject is taken during each of the eight terms of residence.

During the first year each student takes one of five two-term sequences: THE WESTERN TRADITION: THE CLASSICAL HERITAGE (21.011) and THE WESTERN TRADITION: THE EUROPEAN HERITAGE (21.012); or IDENTITY AND AUTOBIOGRAPHY: THE NINETEENTH CENTURY (21.013T) and IDENTITY AND AUTOBIOGRAPHY: THE TWENTIETH CENTURY (21.014T); or LANGUAGE, CULTURE, AND COMMUNITY: PRIMITIVE CULTURE AND ANCIENT CIVILIZATION (21.015T) and LANGUAGE, CULTURE, AND COMMUNITY: ELIZABETHAN ENGLAND AND MODERN AMERICA (21.016T); or CONFLICT AND COMMUNITY IN AMERICA (21.017) and CONFLICT AND COMMUNITY IN AMERICA (21.018); or GOD AND LOGIC: THE PHILOSOPHY OF RELIGION IN THE WEST (21.019) and GOD AND LOGIC: THE PHILOSOPHY OF RELIGION IN THE WEST (21.020). The subject matter of the freshman curriculum is drawn in each case from the several disciplines of the Humanities and directed toward certain major achievements of Western intellect, imagination or social development. The interdisciplinary emphasis of the freshman year is followed by a sophomore curriculum in which the student is asked to examine the perspective and the distinctive languages of two separate disciplines in the School of Humanities and Social Science. The sophomore has a choice between two sets of options. In the first set he is asked to elect either LITERATURE: FORMS OF A MAJOR THEME (21.03); or, LITERATURE: SELF, NATURE AND SOCIETY (21.031); or, PHILOSOPHY: CLASSIC AND CONTEMPORARY (21.04). In the second option he is asked to make a choice between THE TWENTIETH CENTURY: REVOLUTION AND TOTALITARIANISM (21.05); or THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS (21.06); or SOCIETY AND MAN (17.01). Frequent written exercises, with criticism from instructors and scheduled conferences, give each student an opportunity to improve his capacity for clear, critical writing. 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 variations of the first- and second-year humanities subjects are conducted in French and German by the Department of Modern Languages and Linguistics.

Every undergraduate is required to 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 Lan-

(*text continues on page 55*)

HUMANITIES FIELDS AND SUBJECTS

FIRST YEAR[1]

One of the following combinations of subjects:

THE WESTERN TRADITION: THE CLASSICAL HERITAGE (21.011) *and*
THE WESTERN TRADITION: THE EUROPEAN HERITAGE (21.012)

or

IDENTITY AND AUTOBIOGRAPHY: THE NINETEENTH CENTURY (21.013T) *and*
IDENTITY AND AUTOBIOGRAPHY: THE TWENTIETH CENTURY (21.014T)

or

LANGUAGE, CULTURE, AND COMMUNITY: PRIMITIVE CULTURE AND ANCIENT CIVILIZATION (21.015T) *and*
LANGUAGE, CULTURE, AND COMMUNITY: ELIZABETHAN ENGLAND AND MODERN AMERICA (21.016T)

or

CONFLICT AND COMMUNITY IN AMERICA (21.017) *and*
CONFLICT AND COMMUNITY IN AMERICA (21.018)

or

GOD AND LOGIC: THE PHILOSOPHY OF RELIGION IN THE WEST (21.019) *and*
GOD AND LOGIC: THE PHILOSOPHY OF RELIGION IN THE WEST (21.020)

or

THE GREEK TRADITION (23.011)[2] *and*
THE JUDAEO-CHRISTIAN TRADITION (23.021)[2]

or

THE WESTERN TRADITION: THE CLASSICAL HERITAGE (21.011) *and*
THE EUROPEAN TRADITION: GOETHE ERA (23.022)[3]

SECOND YEAR[1]

One of the following subjects:

LITERATURE: FORMS OF A MAJOR THEME (21.03)
LITERATURE: SELF, NATURE AND SOCIETY (21.031)
PHILOSOPHY: CLASSIC AND CONTEMPORARY (21.04)
THE NATURE OF LITERATURE (23.031)[2]
THE NATURE OF LITERATURE (23.032)[3]

and one of the following subjects:

SOCIETY AND MAN (17.01)
THE TWENTIETH CENTURY: REVOLUTION AND TOTALITARIANISM (21.05)
THE TWENTIETH CENTURY: SOCIETY AND CONSCIOUSNESS (21.06)
THE FRENCH ENLIGHTENMENT (23.051T)[2]
THE TWENTIETH CENTURY: REVOLUTION, WAR, AND "TOTALISM" (23.052)[3]

THIRD AND FOURTH YEARS[1]

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

FIELD ONE: HISTORY

(For additional and related subjects see the special Interdisciplinary Sequence on p. 53.)

Any three of the following:

PRE-INDUSTRIAL EUROPE (21.41)†
HISTORY OF ENGINEERING (21.411)†
HISTORY OF ENGINEERING (21.412)†
HISTORY OF MATERIALS (21.414)†
TECHNOLOGY AND ECONOMIC GROWTH (21.415)†
DEVELOPMENT OF AMERICAN ECONOMIC INSTITUTIONS (21.421)†
HISTORY OF TRANSPORTATION IN THE UNITED STATES (21.422)†
THE BUSINESSMAN IN AMERICAN HISTORY (21.424)†
HISTORY OF TECHNOLOGY IN THE UNITED STATES (21.426)†
INTRODUCTION TO SOCIAL ANTHROPOLOGY (21.452)†
NEAR EASTERN ARCHAEOLOGY: THE FOUNDATIONS OF CIVILIZATION (21.454)†
PEASANT SOCIETY (21.455)†
ECONOMIC ANTHROPOLOGY (21.456)†
CULTURES AND SOCIETIES OF MEXICO (21.459)†
THE EMERGENCE OF MODERN AFRICA (21.463)
ROME: REALITY AND IDEA (21.473)†
CULTURE AND SOCIETY IN MEDIEVAL EUROPE (21.475)†
THE ITALIAN RENAISSANCE (21.476)†
THE NORTHERN RENAISSANCE AND THE REFORMATION (21.478)†
SOCIAL CRITICISM IN AMERICA FROM TOCQUEVILLE TO RIESMAN (21.482)†
DISSENT AND REFORM IN TWENTIETH-CENTURY AMERICA (21.483)†
THE NEGRO, THE GHETTO AND THE RIOTS OF THE SIXTIES (21.484)
SCIENCE AND NATURAL PHILOSOPHY IN CHINESE TRADITION (21.512)
INTELLECTUAL HISTORY OF MODERN EUROPE (21.515)†
RUSSIA: ORTHODOXY, AUTOCRACY, AND REBELLION (21.517)†
IDEOLOGIES OF ELITE AND VIOLENCE (21.519)†
MARX, DARWIN, AND FREUD (21.522)†
HISTORY AND PSYCHOANALYSIS (21.524)†
AMERICAN INTELLECTUAL HISTORY (21.531)†
AMERICAN IDEAS AND INSTITUTIONS (21.532)†
THE AMERICAN REVOLUTION (21.541)
CHINESE FOREIGN RELATIONS IN THE NINETEENTH AND TWENTIETH CENTURIES (21.542)†
CHINA, JAPAN, AND THE WEST (21.543)†
FRANCE: THE MODERNIZATION OF A DEVELOPED SOCIETY (21.544)†
WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (21.545)†
NATIONALISM AND POLITICS IN CENTRAL EUROPE FROM THE FRENCH REVOLUTION TO THE THIRD REICH (21.547)†
VIENNA AND VERSAILLES (21.548)†
THE IMPACT OF THE WEST ON AFRICA (21.549J)
RUSSIAN REVOLUTION AND THE SOVIET UNION (21.552)†
SPANISH CIVIL WAR, 1936–1939 (21.554)†
SOVIET-AMERICAN DIPLOMACY (21.556)†
RECONSTRUCTION OF EUROPE, 1945–1965 (21.558)†
NINETEENTH CENTURY EUROPEAN LIBERALISM: ITS DECLINE AND TRANSFORMATION (21.574)†
VARIETIES OF FASCISM: ORIGINS AND COMPARATIVE DEVELOPMENT IN GERMANY AND FRANCE, 1900–1945 (21.576)†
MODERNIZATION IN CHINESE STATE AND SOCIETY (21.577)†
SCIENCE AND PHILOSOPHY FROM ARCHAIC ANTIQUITY TO COPERNICUS (21.701)†
ORIGINS OF MODERN SCIENTIFIC THOUGHT (21.702)

FIELD TWO: PHILOSOPHY

(For additional and related subjects see the Special Interdisciplinary sequence on page 53.)

Any three of the following:

HISTORY OF PHILOSOPHY I (21.611)
HISTORY OF PHILOSOPHY II (21.612)

(*list continued on page 52*)

[1] Each subject in the program for the first and second years carries 3–0–6 units of credit. Each subject in the program for the third and fourth years carries 8 units of credit, unless otherwise specified.

[2] Open only to students having an adequate background in French.

[3] Open only to students having an adequate background in German.

Undergraduate

UNDERGRADUATE HUMANITIES PROGRAM

(list continued from page 51)

CLASSICAL PHILOSOPHY (21.613)†
PHILOSOPHY OF HISTORY (21.617)†
SOCIAL THEORY FROM MARX TO THE PRESENT (21.618)†
SYMBOLIC LOGIC (21.641)†
ETHICS (21.644T)
THEORY OF KNOWLEDGE (21.647)
PROBLEMS IN ETHICS (21.652)†
NATURE AND JUSTIFICATION OF LIBERTY (21.653)†
PHILOSOPHICAL ANTHROPOLOGY (21.668)†
PHILOSOPHY OF THE ARTS (21.671)†
PHILOSOPHY IN LITERATURE (21.672)†
PHILOSOPHIES AND RELIGIONS OF ASIA (21.691)†
RELIGIOUS PHILOSOPHY IN THE WEST (21.692)†
PHILOSOPHY OF RELIGION (21.693)†
SCIENCE AND PHILOSOPHY FROM ARCHAIC ANTIQUITY TO COPERNICUS (21.701)†
ORIGINS OF MODERN SCIENTIFIC THOUGHT (21.702)
PHILOSOPHY OF SCIENCE (21.712)

FIELD THREE: LITERATURE

(For additional and related subjects see the Special Interdisciplinary sequence on page 53.)

LITERARY ANALYSIS (21.11)†‡
plus any two of the following:
INTRODUCTION TO THE WRITING OF FICTION (21.101T)
THE WRITING OF FICTION (21.102)†
THE WRITING OF POETRY (21.103)†
CRITICISM AND CULTURE (21.122)
THE EPIC (21.13)
THE BIBLE (21.14)
SHAKESPEARE (21.15)
CHAUCER (21.16)
LITERATURE OF THE ENGLISH RENAISSANCE (21.17)
NATURE OF POETRY (21.24)
NARRATIVE FICTION (21.27)
THE SHORT STORY (21.276)
DRAMA AND COMMUNITY (21.281)
MODERN DRAMA (21.282)
COMEDY (21.284)
AMERICAN FOLKLORE (21.285)
DOSTOEVSKY, TOLSTOI, CHEKHOV: RUSSIA AND THE MODERN AGE (21.29)
NON-WESTERN LITERATURE (21.301)
CHINESE LITERATURE (21.302)
FOUR IRISH WRITERS: SYNGE, YEATS, JOYCE, AND O'CASEY (21.31)
THE CONFESSION IN LITERATURE (21.312)
MAJOR AUTHORS: MARCEL PROUST (21.313)
MAJOR AUTHORS: WILLIAM BUTLER YEATS (21.314)
STUDIES IN LITERATURE AND NATIONAL VALUES (21.317)
SOCIAL VISION IN LITERARY ART: SHAW, LAWRENCE, FAULKNER (21.35T)
INDIVIDUAL AND ENVIRONMENT IN MODERN LITERATURE (21.36)
SOURCES OF MODERNISM (21.38)
LITERATURE TODAY (21.381)
THE LYRIC FORM OF CONSCIOUSNESS (21.382)
THE MODERN GERMAN NOVEL (23.24)§
MODERN GERMAN DRAMA (23.26)§
DANTE I (23.87)†
DANTE II (23.88)†
SOVIET RUSSIAN LITERATURE (23.951)§
GOGOL AND LITERARY METHODOLOGY IN RUSSIA (23.961)§
MAYAKOVSKY AND PASTERNAK (23.981)§
TOLSTOI'S "WAR AND PEACE" (23.991)§
CONTEMPORARY SOVIET LITERATURE (23.993)§

FIELD FOUR: MODERN LANGUAGES

Group A — German

ADVANCED GERMAN (23.14)¶
or
LITERARY ANALYSIS (21.11)†‡
plus any two of the following:
GOETHE'S POETRY (23.15)†
GERMAN ROMANTICISM (23.16)†
GOETHE'S "FAUST" (23.19)†
SEMINAR IN GERMAN POETRY (23.20)
MODERN GERMAN DRAMA (23.21)†
MODERN GERMAN FICTION (23.22)†
THE MODERN GERMAN NOVEL (23.24)§
MODERN GERMAN DRAMA (23.26)§

Group B — French

CONVERSATIONAL FRENCH (23.54)¶
or
LITERARY ANALYSIS (21.11)†‡
plus any two of the following:
CONTEMPORARY FRENCH DRAMA (23.61T)
FRENCH ROMANTICISM (23.62T)
FRENCH PROSE FICTION (23.63)†
SEMINAR IN FRENCH LITERATURE (23.64)
CLASSICAL FRENCH DRAMA (23.65)
MODERN FRENCH POETRY (23.66)

Group C — Russian

INTRODUCTION TO RUSSIAN LITERATURE (23.941)†
or
LITERARY ANALYSIS (21.11)†‡
plus any two of the following:
SELECTED PROBLEMS IN NINETEENTH-CENTURY RUSSIAN LITERATURE (23.95)†
SEMINAR IN MODERN RUSSIAN POETRY (23.96)†
SELECTED PROBLEMS IN SOVIET LITERATURE (23.98)†
SEMINAR IN RUSSIAN PROSE (23.99)†

Group D — Spanish

INTRODUCTION TO SPANISH LITERATURE (23.41)†
or
LITERARY ANALYSIS (21.11)†‡
plus any two of the following:
SPANISH DRAMA (23.35)
TWENTIETH-CENTURY SPANISH LITERATURE (23.36)
MASTERPIECES OF SPANISH LITERATURE (23.42)

Group E — Comparative Literature

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

FIELD FIVE: MUSIC

MATERIALS OF MUSIC (21.81)*
and
INTRODUCTION TO MUSIC (21.82)†
plus one of the following:
MUSIC THEORY I (21.821)
MUSIC THEORY II (21.822)
PROBLEMS AND TECHNIQUES OF MUSIC RESEARCH (21.823)
MUSICAL FORM AND ANALYSIS (21.824)
ORCHESTRATION (21.825)
WESTERN MUSIC IN THE MIDDLE AGES AND THE RENAISSANCE 21.83)
WESTERN MUSIC IN THE BAROQUE ERA (21.84)
WESTERN MUSIC IN THE CLASSIC ERA (21.85)
WESTERN MUSIC IN THE ROMANTIC ERA (21.86)

* Students may omit 21.81 if they have adequate background for 21.82. In this case they should select one additional subject from Field Five.

‡ Students who elect 21.03 or 21.031 or 23.031 or 23.032 in partial fulfillment of their second-year humanities requirement are to take three subjects, in place of two, from the list in Field Three: Literature. If 21.03 or 21.031 or 23.031 or 23.032 are taken, 21.11 may not be taken for credit.

¶ Accepted as one subject in the humanities and social sciences.

§ Readings in English; conducted in English.

(list continues on page 53)

TWENTIETH-CENTURY MUSIC (21.871)
TWENTIETH-CENTURY MUSIC: SCHOENBERG, BERG AND WEBERN (21.872)
THE OPERA (21.88)
SEMINAR IN MUSIC (21.891)
SEMINAR IN MUSIC (21.892)

FIELD SIX: ECONOMICS

ECONOMIC PRINCIPLES I (14.01) †
and
ECONOMIC PRINCIPLES II (14.02)
and one of the following:
PRICES AND PRODUCTION (14.03)
ECONOMIC FLUCTUATIONS AND GROWTH (14.05)
INDUSTRIAL ORGANIZATION AND PUBLIC POLICY (14.20)
DISTRIBUTION OF INCOME AND EMPLOYMENT OPPORTUNITY (14.41)
URBAN ECONOMICS (14.51)
ECONOMICS OF THE SOVIET UNION (14.52)
COMPARATIVE ECONOMIC SYSTEMS (14.53)
LABOR ECONOMICS AND PUBLIC POLICY (14.64)
ECONOMIC HISTORY (14.71)
ECONOMIC GROWTH AND DEVELOPMENT (14.74)

FIELD SEVEN: POLITICAL SCIENCE

Any three of the following subjects:
THE MODERN WORLD AND SOCIAL SCIENCE (17.02) †
POWER, INFLUENCE, AND POLICY DECISIONS (17.14)
POLITICAL PSYCHOLOGY (17.15)
THE AMERICAN POLITICAL PROCESS (17.21) †
STRUCTURE OF URBAN LIFE (17.22) *
SEMINAR IN CONTEMPORARY URBAN SOCIOLOGY (17.23)
COMPARATIVE POLITICAL SYSTEMS (17.24) †
STATE AND LOCAL POLITICS (17.25)
THE POLITICS OF NATIONAL ECONOMIC CONTROL (17.26)
BUREAUCRACY (17.27)
POLITICAL PARTIES (17.28)
EVOLUTION OF STRATEGIC NUCLEAR SYSTEMS (17.31)
EVOLUTION OF FORCES FOR LIMITED WAR (17.32)
GOVERNMENT, POLITICS AND TECHNOLOGY (17.42)
INTERNATIONAL RELATIONS (17.51) †
PRINCIPLES AND PROBLEMS OF AMERICAN FOREIGN POLICY (17.52)
SEMINAR IN INTERNATIONAL POLITICS (17.53)
ARMS CONTROL, DISARMAMENT, AND FOREIGN POLICY (17.54)
POLITICAL AND ECONOMIC DEVELOPMENT OF TROPICAL AFRICA (17.61)
THE IMPACT OF THE WEST ON AFRICA (17.62J)
SEMINAR: MECHANISMS AND FORMS OF PROTEST (17.63)§
POLITICAL SCIENCE SEMINAR (17.64)
MATHEMATICAL POLITICS (17.73)
PREDICTION IN SOCIAL SCIENCE AND PUBLIC POLICY (17.75)

FIELD EIGHT: LABOR RELATIONS

Group A

ECONOMIC PRINCIPLES I (14.01) †
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
DISTRIBUTION OF INCOME AND EMPLOYMENT OPPORTUNITY (14.41)

FIELD NINE: PSYCHOLOGY

INTRODUCTORY PSYCHOLOGY (9.00) †
and any two of the following subjects:
PHYSIOLOGICAL PSYCHOLOGY I (9.01)
PHYSIOLOGICAL PSYCHOLOGY II (9.02)
NEURAL MECHANISMS OF LEARNING AND MOTIVATION (9.03)
COMPARATIVE PSYCHOLOGY (9.30)
PSYCHOLOGY OF PERCEPTION (9.35)
LEARNING (9.40)
PROBLEM SOLVING (9.45)
PSYCHOLOGY OF LANGUAGE AND COMMUNICATION (9.59)
PERSONALITY STRUCTURE AND DEVELOPMENT (9.60)
SOCIAL PSYCHOLOGY (9.70)
BEHAVIOR IN GROUPS (9.80)
SEMINAR IN THE ORIGINS OF BEHAVIOR (9.88)
DEVELOPMENTAL PSYCHOLOGY (9.89)
ADVANCED PSYCHOLOGY SEMINAR (9.92) §

FIELD TEN: VISUAL ARTS

Three subjects: selections within both groups required

Group A

VISUAL DESIGN PROBLEMS I (4.021)
VISUAL DESIGN PROBLEMS II (4.022)
CREATIVE PHOTOGRAPHY I (4.051T) †
CREATIVE PHOTOGRAPHY II (4.052T)
PAINTING (4.071)

Group B

EVALUATING PHOTOGRAPHY (4.053T)
TOPICAL STUDIES IN THE HISTORY AND THEORY OF ART (4.601) †
INTRODUCTION TO MODERN ART (4.602) †
PAINTING AND SCULPTURE IN THE MIDDLE OF THE NINETEENTH CENTURY (4.603) †
MODERN ART FROM POST-IMPRESSIONISM TO CUBISM (4.604) †
PAINTING IN THE TWENTIETH CENTURY (4.605) †
SCULPTURE IN THE TWENTIETH CENTURY (4.606) †
ARCHITECTURE IN THE ANCIENT WORLD (4.61) †
ARCHITECTURE 1400–1750 (4.62) †
ARCHITECTURE IN THE MIDDLE AGES (4.63) †
ARCHITECTURE FROM 1750 TO THE PRESENT (4.64) †

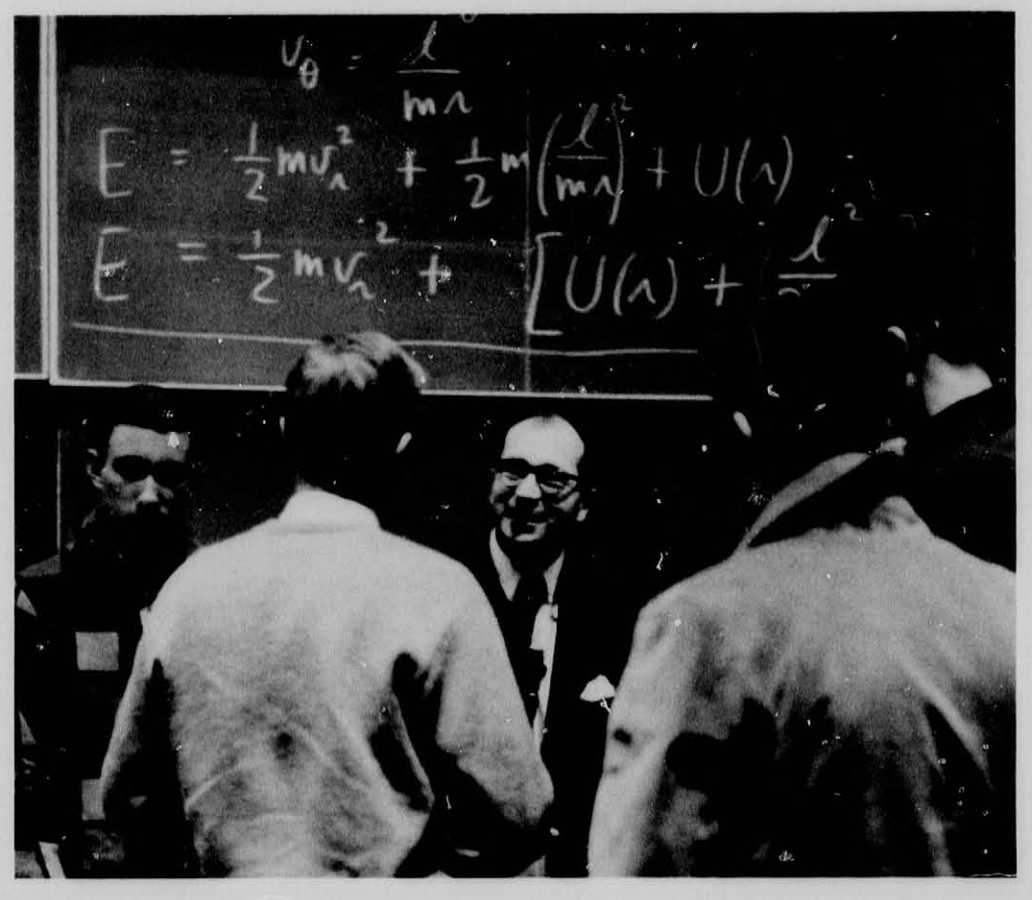
SPECIAL INTERDISCIPLINARY SUBJECTS‡

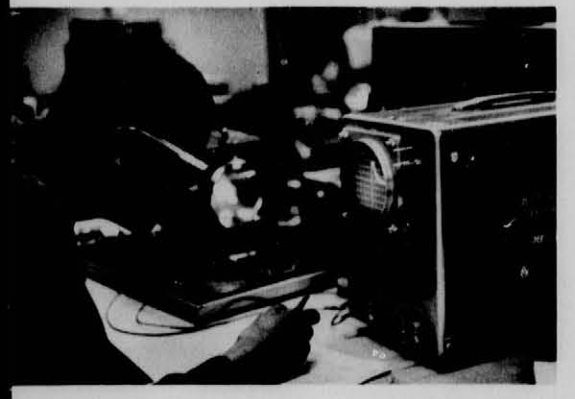
POETIC AND SCIENTIFIC DISCOURSE IN CLASSICAL LITERATURE (21.95)
INTRODUCTION TO THE FAR EAST (21.951) †
PROBLEMS IN CONTEMPORARY PHILOSOPHY AND THEOLOGY: THE PROBLEM OF GOD (21.96)
RELIGION AND SOCIETY IN AMERICA (21.964)
SEMINAR ON BOSTON (21.965)
BIOLOGICAL BASES OF PERCEPTION AND KNOWLEDGE (21.97) †
HISTORY OF ATOMIC THEORY (21.98)
E. M. FORSTER (21.99T)
UTOPIAN LITERATURE (21.991)
TRADITION AND INNOVATION IN TWENTIETH-CENTURY PHYSICS (21.992)
FILM AND THE ANTHROPOLOGICAL IMAGINATION (21.993T)
INTELLECTUALS AND SOCIAL CHANGE (21.995) †
AMERICAN VALUES OF THE 1920's (21.996)
THE CONCEPT OF FREEDOM IN MODERN LITERATURE (21.997)
LITERATURE AND COMMUNICATION (21.998T)
ANALYSIS AND SYNTHESIS OF MUSICAL SOUNDS (21.999)

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

‡ Subjects in this category are additional subjects which may be taken to satisfy the Humanities distribution requirement; but they may also be combined, by petition to the Humanities Department, with other elective subjects in the above ten fields to satisfy the concentration requirement of three subjects in a single field.

§ A "time arranged" subject. At least 8 units must be taken to be accepted as one subject in the humanities and social sciences.


$v_\theta = \frac{l}{mr}$
$E = \frac{1}{2}mv_r^2 + \frac{1}{2}m\left(\frac{l}{mr}\right)^2 + U(r)$
$E = \frac{1}{2}mv_r^2 + \left[U(r) + \frac{l^2}{2mr^2}\right.$







guages, Music, Economics, Political Science, Labor Relations, Psychology, and Visual Arts. In addition, some special interdisciplinary subjects are available, mainly serving as distributional subjects.

The humanities or social science field is selected on a basis of particular interest, except that students enrolled in Shipping and Shipbuilding Management (Course XIII-B) or Economics (Course XIV) may not select either the Economics or Labor Relations fields; and those in Political Science (Course XVII) may not select the Political Science field. Students in Architecture (Course IV) may not select certain subjects to satisfy the humanities and social science program, as specified under the Course IV curriculum.

The subject offerings are described on the preceding 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 subject which must be taken by all undergraduates in the School of Architecture; and in the School of Engineering by those in Civil Engineering (Course I) and Naval Architecture and Marine Engineering (Course XIII). It may be taken either as the distributional subject or as part of an appropriate three-term concentration.

Military Science, Aerospace Studies, and Naval Science

The general object of the Reserve Officers' Training Corps is to qualify students as officers in the active and reserve forces as well as for positions of leadership in civilian pursuits. The Army, Navy, and Air Force each conducts a program at M.I.T. for this purpose.

THE ARMY R.O.T.C. PROGRAM

Full-time students who are U.S. citizens and who meet required medical standards may enroll for military science and earn commissions as Army Second Lieutenants while they pursue their regular academic Courses. Books, uniforms, and equipment required for the program are furnished.

Four years of classroom work or the completion of the Basic Summer Camp in lieu of the first two years of classroom work, and a six-week Advanced Summer Camp qualify students for commissions upon graduation. The curriculum is designed to provide a challenging and academically oriented course of study which is directed toward the achievement of a professional educational objective. Emphasis is placed upon individual development using the lecture, seminar, guest lectures, and programmed instruction as an instructional methodology.

The Military Science Program consists of two divisions:

1. *Pre-Professional Division.* The objective during these two years is to provide the student with a greater perspective and deeper understanding of the historical and political evolution of the military institution and its role in international affairs.
2. *Professional Division.* The objective during these two years is to develop the student's understanding and capabilities in the application of the principles and techniques of leadership and management, with emphasis on organizational behavior and the effective and economical employment of men and materiel.

Between the third and fourth years, the student attends a six-week Advanced Summer Camp conducted within a military environment. Reinforcement of classroom instruction is accomplished through the use of practical field training. Major emphasis is given to leadership development by placing the student into actual leadership positions.

Students receive $50 per month during their junior and senior years. They are also paid for the Advanced Summer Camp and Basic Summer Camp according to the current active duty pay scale. Mileage allowances are paid for travel to and from the summer camp.

Two- and four-year scholarships covering full tuition, fees, and a monthly stipend of $50 are available on a competitive basis to those students who plan to enroll in the four-year R.O.T.C. program. Details may be obtained by writing to the Professor of Military Science at the Institute prior to December 1 of the year preceding the year the student plans to enter M.I.T.

Students in the Army R.O.T.C. program must, while completing degree requirements in one of the M.I.T. Courses, take the following required subjects in military studies:

FIRST YEAR

First Term

MS 11 WORLD MILITARY HISTORY (2–1–1)
(M.I.T. elective credit)

Second Term

MS 12 WAR AND THE MILITARY INSTITUTIONS OF THE MODERN STATE (2–1–1)
(M.I.T. Elective credit)

SECOND YEAR*

First Term

MS 21 NATIONAL SECURITY AND THE CONCEPT OF FORCE (2–1–1)
(M.I.T. elective credit)

Second Term

MS 22 NATIONAL SECURITY AND THE CONCEPT OF FORCE (2–1–1)
(M.I.T. elective credit)

* Recommended sequence as shown, however, may be interchangeable with third- and fourth-year subjects.

THIRD YEAR

First Term

MS 31 CONCEPTS AND APPLICATIONS OF MILITARY SCIENCE (2–1–1)
(No M.I.T. credit)

Second Term

MS 32 CONCEPTS AND APPLICATIONS OF MILITARY SCIENCE (2–1–1)
(No M.I.T. credit)

FOURTH YEAR

First Term

MS 41 PRINCIPLES AND TECHNIQUES OF PROFESSIONAL LEADERSHIP (2–1–1)
(No M.I.T. credit)

Second Term

MS 42 PRINCIPLES AND TECHNIQUES OF PROFESSIONAL LEADERSHIP (2–1–1)
(No M.I.T. credit)

The Two-Year Program

The two-year program is designed specifically for those students who have not taken Army R.O.T.C. during their first two undergraduate years or for graduate students who have never had Army R.O.T.C. Such students may apply during the year preceding the year in which they desire to be enrolled in the two-year program. Selections are based on nationwide competition and initial processing is initiated in January of each school year. The student can take advantage of this program by attending a six-week basic summer camp prior to being enrolled in the Advanced Course R.O.T.C. The basic summer camp takes the place of Basic R.O.T.C. on campus.

Eligibility Requirements

To be eligible for the Army 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 Army Reserve in accordance with existing Army regulations.
3. Not under 14 years of age; and upon graduation not more than 28 years of age.
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 and enlist in the Army Reserve at the beginning of the Advanced Course, 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 Army upon commissioning.

Application Procedure

Eligible students should apply for admission to the Army R.O.T.C. after they have been notified of admission to the Institute. Application should then be made through the Professor of Military Science, either by mail or by personal visit as soon as possible. Further information, including physical standards, will be forwarded upon receipt of an initial application.

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 Department of Aerospace Studies offers two programs — one of four years and one of two years — for M.I.T. students to qualify for commissions.

The Four-Year Program

The four-year 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 the major military forces of the world and develops an understanding of how the United States Air Force serves national interests in the modern context of international relations. 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 by discussing military and aerospace technological advances and current research and development activities. 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 training.

While in an undergraduate status, Air Force R.O.T.C. students are furnished all text and reference books, uniforms, and equipment re-

quired for aerospace study. Under the provisions of the Reserve Officers Training Corps Vitalization Act of 1964, Air Force R.O.T.C. cadets in the four-year program are offered an opportunity to compete, on a nationwide basis, for full scholarship assistance which includes tuition, laboratory fees, and books, plus a subsistence allowance of $50 per month during their sophomore, junior, and senior years. Those students who do not obtain a scholarship will receive $50 monthly during their junior and senior years.

At the beginning of the junior year each student is required to sign a formal agreement that he will complete the Professional Officer Course 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. Also, at the beginning of the junior year the student is sworn into the Enlisted Reserve of the United States Air Force. The term of active duty commitment after commissioning varies depending upon the professional area chosen. For those entering research and development, engineering, or any other non-flying 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 six years.

Students in the Air Force R.O.T.C. program must, while completing degree requirements in one of the M.I.T. Courses, take the following required subjects in aerospace studies:

FIRST YEAR

First Term

AS 11 WORLD MILITARY SYSTEMS (3–1–3)
(M.I.T. elective credit)

Second Term

AS 12 AIRPOWER AND WORLD MILITARY SYSTEMS (3–1–3)
(M.I.T. elective credit)

SECOND YEAR

First Term

AS 21 AEROSPACE SYSTEMS I (0–1–0)
(No M.I.T. credit)

Second Term

AS 22 AEROSPACE SYSTEMS II (0–1–0)
(No M.I.T. credit)

THIRD YEAR

First Term

AS 31 SEMINAR IN GROWTH AND DEVELOPMENT OF AEROSPACE POWER (3–1–1)
(No M.I.T. credit)

Second Term

AS 32 SEMINAR IN GROWTH AND DEVELOPMENT OF AEROSPACE POWER (3–1–1)
(No M.I.T. credit)

FOURTH YEAR

First Term

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

Second Term

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

The Two-Year Program

The two-year program is for those students who do not complete the first two years (general military education program) of the four-year Air Force R.O.T.C. program. Such students may apply during their sophomore year for acceptance into the two-year program. In lieu of completing the freshman and sophomore years of the four-year program, these men will receive field training in a six-weeks' Officer Training Course conducted on an Air Force base during the summer between the sophomore and junior years. Upon successful completion of the six-week intensive military and academic program, they will return to the campus to be enrolled in the Professional Officer Course. They will receive $50 a month in subsistence allowance and complete the same academic program required of the upper-class four-year students.

General Information on Both Programs

Adjustment in the aerospace program will be made to accommodate students enrolling in an honors or cooperative Course. Students who are eligible for and desire graduate training immediately after completing their undergraduate work may:

1. Request a delay in reporting for active duty until completing graduate training.
2. Submit an application to the Air Force Institute of Technology for graduate training at Air Force expense immediately after commissioning.
3. Request an assignment at an educational institution to pursue graduate training under a fellowship grant.

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 30 years of age.
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 and enlist in the Air Force Reserve 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.

Application Procedure

Eligible students should apply for admission to the Air Force R.O.T.C. after they have been notified of admission to the Institute. Application should then be made directly to the Professor of Aerospace Studies, either by mail or by personal visit as soon as possible. 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 Aerospace Studies after considering and evaluating such factors as past academic record, leadership displayed in high school activities, personal motivation, and potential officer capabilities.

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 or science curricula, will qualify selected male students for commissions as Naval Reserve Officers in the restricted line category (engineering duty only).

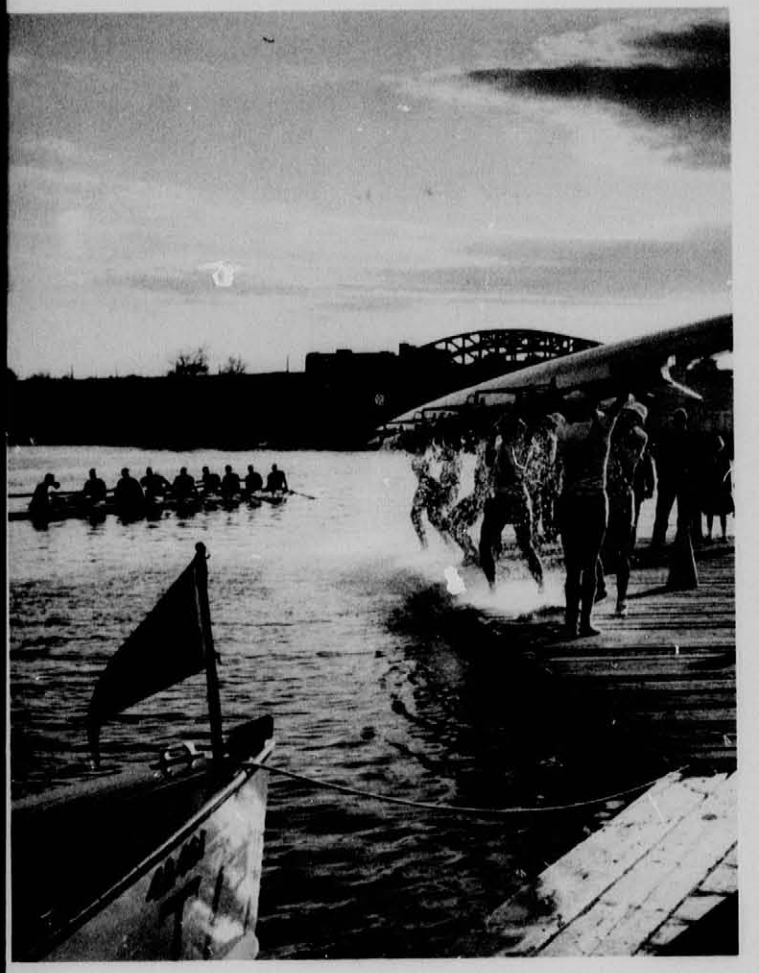
The M.I.T. Navy unit is the only one of the 54 nation-wide Naval R.O.T.C. programs designed to produce solely "engineering duty only" officers. Graduates of this program may serve their obligatory active duty as engineering officers aboard ship, in naval shipyards, or in other technical assignments. Students may apply for the Navy Nuclear Power Program or for Submarine or Flight Training, or they may 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 Naval R.O.T.C. 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 six to eight 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 and all uniforms and uniform equipment, and in addition he receives retainer pay of $50 per month 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 $160 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 three years, unless he plans to attend graduate school, as noted above. At the end of this three-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.

In addition to the standard four-year Naval R.O.T.C. program, the Navy now has a two-year program for which sophomores may apply. Sophomores enrolled in this program attend a six-week summer training session at specified colleges between their sophomore and junior years. This summer training consists of both classroom and laboratory sessions designed to put the student on a level with his fellow Naval R.O.T.C. students at the start of the junior year. The material covered is comparable to the first two years of Naval Science subjects.

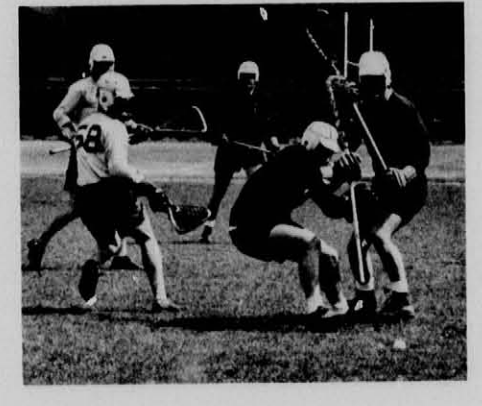
Upon completion of summer training and enrollment in the Naval R.O.T.C. program, the two-year student takes the same subjects as the four-year student during his junior and senior years. He receives all text and reference books required for the Naval Science course and all uniforms and uniform equipment, and receives retainer pay of $50 per month during his third and fourth academic years. In addition, he must take six weeks practical engineering training at sea aboard a naval ship, normally during the summer between the third and fourth academic years. The active duty and reserve requirements are the same as for the four-year program.











Eligibility Requirements

To be eligible for the four-year Naval R.O.T.C. program, an entering student must be:

1. A male citizen of the United States.

2. At least 17 years of age and not more than 21 years of age by June 30 of the year in which enrolled in the program. The lower age limit may be reduced to 16 years if the student is considered of sufficient maturity to take Naval Science courses.

3. Physically 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.

4. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any Course except the following: Cooperative Courses II-B, VI-A, X-B, and XVI-B; Architecture IV; Life Sciences VII; Economics XIV; Political Science XVII; and Humanities and Engineering XXI. Students in Architecture, Life Sciences, Economics, Political Science and Humanities will be considered for eligibility provided they complete as part of their elective and science distribution subjects at least eight subjects from the required core curriculum for an S.B. degree in any single department within the Schools of Science and Engineering.

5. 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 three years subsequent to graduation, and to retain the commission for a period of six years from the date of original acceptance.

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

1. A male citizen of the United States.

2. A sophomore in good standing with not less than a C average.

3. At least 18 years of age upon enrollment and of such age that he will not have reached the 25th anniversary of birth on June 30 of the year in which he will receive a Baccalaureate Degree and complete all requirements for a commission.

4. Physically qualified in accordance with the physical standards prescribed for the four-year Naval R.O.T.C. Program except that visual acuity may be as low as 20/200 correctable to 20/20 with the use of lenses.

5. Planning to pursue work at M.I.T. leading to a Bachelor's degree in any Course except the following: Cooperative Courses II-B, VI-A, X-B, and XVI-B; Architecture IV; Life Sciences VII; Economics XIV; Political Science XVII; and Humanities and Engineering XXI. Students in Architecture, Life Sciences, Economics, Political Science and Humanities will be considered for eligibility provided they complete as part of their elective and science distribution subjects at least eight subjects from the required core curriculum for an S.B. degree in any single department within the Schools of Science and Engineering.

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 three 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. elective credit)

Second Term

NS 12 ORIENTATION AND SEA POWER (3–1–5)
(M.I.T. elective credit)

SECOND YEAR[1]

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[1]

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[1]

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)

[1] INTRODUCTORY PSYCHOLOGY (9.00) must be taken as a prerequisite for NS 42.

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.

Sophomores interested in the two-year Naval R.O.T.C. Program must submit applications to the Commanding Officer, N.R.O.T.C. and

Naval Administrative Unit, M.I.T., prior to March 15 of their sophomore year.

Selective Service Office

M.I.T. undergraduates who are subject to Selective Service will find all the necessary military information at the Institute's Selective Service Office, Room 5-108. The Graduate School Office, Room 3-140, provides similar assistance to graduate students, described in Section 3 of this Catalogue.

Opportunities for Overseas Study

Many opportunities exist for M.I.T. undergraduates to participate in the experience of overseas study.

The Institute has no formal "junior year abroad" program, but M.I.T. undergraduates may enroll in any of a number of well organized and well established programs sponsored by other colleges. While these programs are primarily concerned with studies in languages and the liberal arts, there are possibilities for students who so desire to enroll in subjects in mathematics and the natural sciences at levels comparable to the third year at M.I.T.

Opportunities also exist for students to arrange individual programs at overseas universities. Such programs require careful planning and a mature approach on the part of the student.

Effective working command of the language of instruction is vital. A student without prior study can by hard work achieve such command of a Western European language if he begins by the second term of his freshman year. Early planning is obviously important.

Because of the important differences in academic practices and levels among overseas universities, there are no general rules by which to achieve academic credit for work and study overseas applicable toward M.I.T. degree requirements. It is the responsibility of each student to work out with his own department and Faculty Counselor the arrangements for academic credit for work he proposes to undertake overseas.

Professor Harold L. Hazen, Dean Emeritus of the Graduate School, is Foreign Study Advisor, and he is prepared to discuss opportunities with students and to assist them in planning their programs. Students interested in overseas study should consult him as early as possible for help in organizing their objectives and plans of study, selecting their overseas institutions, and preparing in language studies. M.I.T. is cooperating with a number of international student agencies which contribute greatly in the areas of travel, housing, and hospitality.

Wellesley Exchange Subjects for Undergraduates

Wellesley College and M.I.T. have inaugurated a five-year experimental cross-registration program for undergraduates to extend and diversify the educational programs now available to students in the curricula and the environments of both institutions. Starting in September, 1968, there will be opportunity for a limited number of M.I.T. undergraduates to take subjects at Wellesley College in place of M.I.T. subjects. Details on the exchange, including the rules governing the substitution of required subjects, are provided in a publication entitled *Wellesley-M.I.T. Undergraduate Exchange Program: Guide for M.I.T. Students*, available in the Information Office and in the office of the Dean of Student Affairs. The *Guide* includes a list of Exchange Program Faculty Counselors at both M.I.T. and Wellesley, and students should feel free to consult with them about the program.

Bus transportation will be provided to exchange students without charge, but the bus schedule will be limited.

In order to be eligible to take subjects at Wellesley during the fall term, M.I.T. students must submit an application form to the office of the Dean of Student Affairs by May 1 of the preceding spring.

Cooperative Arrangement with Harvard University

A limited number of M.I.T. undergraduates, usually fourth-year students with excellent academic records, may be permitted to take one or more subjects given at Harvard University for degree credit and at no extra charge. Arrangements to take subjects at Harvard, which must be in areas not covered by regularly offered M.I.T. subjects, are made through the Headquarters of the Department of Humanities.

Costs

M.I.T. is an independent, endowed institution; the tuition of $2,150 per year paid by each stu-

dent covers less than half the cost of facilities and teaching. The balance is met by income from endowment and by gifts.

The Institute believes it essential that each student make a detailed estimate of his expenses, including basic costs, variable personal expenses, and needs for transportation. This estimate should be considered carefully in the light of his resources and of the financial aids which may be available to him.

The following list gives an estimate of the average student's basic costs for the academic year 1968–69 at M.I.T.:

Tuition	$2,150
Board and room	1,170[1]
Books and materials	150
Medical insurance	95[2]
	$3,565

In addition to these costs, about $400 per academic year should be allowed for such expenses as clothes, laundry, and personal necessities. The cost of travel varies with the distance involved, and is not included in the above.

Financial Aid for Undergraduates

The Institute Student Aid Committee awards scholarships and loans on the basis of the financial need of the individual student, as determined by analysis of the Parents' Confidential Statement of personal finances, submitted through the College Scholarship Service of the College Entrance Examination Board. Within the available resources, the Institute will meet this need through the combination of M.I.T. and outside awards; therefore, no candidate for admission should hesitate to apply because of financial circumstances.

Other means of meeting expenses, which are available to all students regardless of need, are described in Section 1 of this Catalogue.

SCHOLARSHIPS

The Student Aid Committee reviews applications and makes awards from the most suitable scholarship resources; *applicants need not request aid from a specific fund.* That portion of an applicant's need which results from travel costs, as fixed by the Committee, will be covered by scholarship funds. Need in addition to travel costs, not met by scholarship, will be offset by long-term, low-interest loans.

LOANS

Loan funds allow the student to pay part of the cost of his education on long-term credit under very favorable financial terms. However, loan fund capital is limited, and low-interest loans are granted only on the basis of financial need as established by the Parents' Confidential Statement.

Loans are provided from a number of sources, including the Institute's own Technology Loan Fund and the National Defense Student Loan Program. Complete details are given in Appendix A.

APPLICATIONS FOR FINANCIAL AID

Entering Freshmen

Students who wish to be considered for financial aid should complete and return the Financial Aid Application which is included with the Final Application for Admission. In addition, a Parents' Confidential Statement (P.C.S.) must be submitted to the College Scholarship Service, designating M.I.T. as a recipient. The P.C.S. form may be obtained from a secondary school or from the College Scholarship Service, P.O. Box 176, Princeton, New Jersey 08540, or P.O. Box 1025, Berkeley, California 94701. Both the application form and the P.C.S. must be submitted prior to January 15.

An application for admission is not prejudiced by an application for aid. There is no reason for a person with the ambition to attend M.I.T. to be deterred from applying concurrently for admission and aid.

Upperclassmen

Most M.I.T. awards are on an annual basis, and recipients are invited to reapply in December or January each year for continued assistance. Upperclassmen, including transfer students who have not received prior assistance, may make application at this time.

Upperclass financial aid application forms are available from the Student Aid Center about December 15. A Parents' Confidential Statement also must be completed, and both forms must be returned to the Student Aid Center no later than February 1.

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

[2] This figure covers a twelve-month period for a single person.

Undergraduate Admission to M. I. T.

The great majority of undergraduate students enter M.I.T. as members of the freshman class, directly following completion of secondary school studies. Each year a limited number of students whose previous studies at other colleges and 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

The size of the first-year class is limited. The Committee on Admissions will give preference to 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

Most good 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 in high school 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 (4)
Algebra (2)
Plane Geometry (1)
Physics (1)
Chemistry (1)
Trigonometry (½)

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. For courses which go beyond the minimum, work in elementary functions, advanced algebra, and such topics as probability and logic is recommended.

In addition to the subjects specifically required, the applicant normally will have completed at least 6 additional units 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 recommended that the elective subjects include 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.

Undergraduate

UNDERGRADUATE ADMISSION

Application Procedure

Upon initial inquiry, applicants will receive information about M.I.T. as well as about the application procedure. At the same time they will receive a Request for Application Material form which may be filed as early as desired in advance of the anticipated date of entrance. Filing of this form will assure that the applicant will receive Final Application forms at the proper time (in the fall preceding the desired date of entrance), any announcements which may be issued, as well as information about a personal conference (as noted below).

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

Interviews (Conferences)

Each applicant for admission to the freshman class is expected, if possible, 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 Request for Application Material 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 are glad to speak with applicants at any time for general information and counseling purposes. If an applicant sees a counselor before the spring of his junior year, he should have another conference with him after May 1 of that year.

Prospective applicants and their families are welcome at the Admissions Office Monday through Friday 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 the following tests given by the College Entrance Examination Board: the Scholastic Aptitude Tests and three one-hour achievement tests; (1) Level I Mathematics *or* Level II Mathematics, (2) Physics *or* Chemistry, (3) English Composition *or* American History and Social Studies *or* European History and World Cultures.

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 College Entrance Examination Board, Box 592, Princeton, New Jersey 08540. (Residents of western North America, Mexico, Australia, Pacific Islands, Japan, and Formosa should apply to the College Entrance Examination Board, Box 1025, Berkeley, California 94701.)

Candidates should plan to complete the required series of tests not later than the January test date of their senior year, but may choose any date they wish or divide the tests among two or more dates in the same or in different years. A student taking physics or chemistry in his junior or 11th-grade year should take the achievement test in that subject, along with the Scholastic Aptitude Test, in May of that year. 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. early in April.

Early Decisions on Applications

M.I.T. requires a complete set of application materials before considering a candidate 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 all the required College Board tests before the senior year and files all of the application material by November 1 of the senior year, he may request the Committee on Admissions to review his application by December 1. If his test scores, school grades through the junior year, and other qualifications are so excellent that he will clearly be acceptable later, the Com-

mittee 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 the colleges' common reply date, May 1 in 1969. A student interested in his academic standing relative to M.I.T.'s standards should consult the published M.I.T. Report to Secondary Schools, 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. Degree credit for M.I.T. subjects, and, where appropriate, advanced placement, is given on the basis of a high achievement in the tests. The student is notified before registration of the placement and/or credit offered so that he may discuss with his Faculty Advisor 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.

Foreign Residents of the U.S. or Canada

Foreign citizens applying for undergraduate entrance from secondary schools inside the United States or Canada must have completed their applications, including College Entrance Examination Board tests, by January 15. They will be expected to have filled the requirements listed in the preceding section.

FOREIGN STUDENTS

Applications for admission from foreign citizens studying abroad should be submitted by March 1. Decisions about admission cannot be made until complete records have been received. Applications received after the March 1 deadline cannot be considered for the September term of that year. It is not possible to admit undergraduates for the February term.

Foreign citizens desiring to apply for entrance to M.I.T. should request final application material at least one year preceding their proposed year of entrance and no later than January 15 of the year of entrance.

Students from British Commonwealth countries must reach the Higher School Certificate level or the "A" level of the G.C.E. in three subjects, two of which should be physics and mathematics. Students from Hong Kong secondary schools should reach the Lower Form VI.

Application Procedure

Final application material includes a formal application form, a school report form and two teacher evaluation forms. All materials should be returned to the Advisor to Foreign Students by March 1. Failure to do so will result in cancellation of the application.

Interviews (Conferences)

Whenever feasible, foreign students will be requested to have a personal conference at a convenient location with a member of the M.I.T. Educational Council. Council members are alumni who have been selected for their interest in and liking for young people and for their ability to represent M.I.T. They welcome the opportunity to meet students interested in M.I.T. and to help them in their educational plans.

Students also may be requested to have an interview with an educational agency.

If a student is requested to have an interview, it is important that this requirement be filled before the March 1 deadline.

Entrance Examinations

Candidates graduating from secondary schools and applying for the first-year class are expected to take a series of tests given by the College Entrance Examination Board. These are given in various centers around the world several times each year. They should be taken in December, January, or March in order that the scores may be sent to M.I.T. before the application deadlines.

Candidates are expected to take the one-hour Achievement Tests in Level I or Level II mathematics, physics, and chemistry. The English composition test may be taken in place of either (but not both) the physics or chemistry test. Registration material should be requested from the College Entrance Examination Board at the appropriate address noted in the preceding section on Entrance Examinations.

Foreign first-year applicants whose native language is not English and whose schooling has not been predominantly in English must take the Test of English as a Foreign Language (TOEFL), administered by the Educational Testing Service, Princeton, New Jersey 08540, U.S.A. The test is given in one session lasting about three and one-half hours in most of the major cities of the world. Candidates pay a fee of $10 by International Money Order made payable to the Educational Testing Service. It is recommended that applicants take the test by January, 1969. Test registration forms and information regarding the test can be secured by writing to the Educational Testing Service at the above address.

Expenses

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. For details regarding expenses at M.I.T., please refer to the preceding section on Costs.

Application material and further information about the admission of foreign students is available from the Advisor to Foreign Students, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, U.S.A.

COLLEGE TRANSFERS

Students who have completed two 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.

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

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 credit for subjects of study completed elsewhere which are substantially equivalent to corresponding Institute subjects. A grade above the lowest passing grade is necessary.

Students whose records appear not to warrant 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.

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

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.

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 the Bursar, M.I.T., is preferred.

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

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

4. Three evaluation reports, including two from faculty instructors and one from the Dean of Students or the applicant's chief faculty advisor. These forms should be sent directly to the Director of Admissions from the endorsers.

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.

Students who have attended another college will not be eligible for scholarship aid until they have satisfactorily completed one term of work at M.I.T. but will be considered for loan assistance during their first term in attendance.

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.

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 scholarship aid but may be considered for loan assistance during their first term 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.

Foreign Transfers

Foreign students applying for admission with advanced standing should refer to the preceding section on College Transfers, noting that they are required to take part or all of the test program. The tests may be waived by the Committee on Admissions for candidates who are enrolled in programs which have substantial amounts of advanced college work in physics, chemistry, and mathematics.

The usual $10 application fee is not required of foreign students, except those studying or living in the United States or Canada and those of Canadian citizenship.

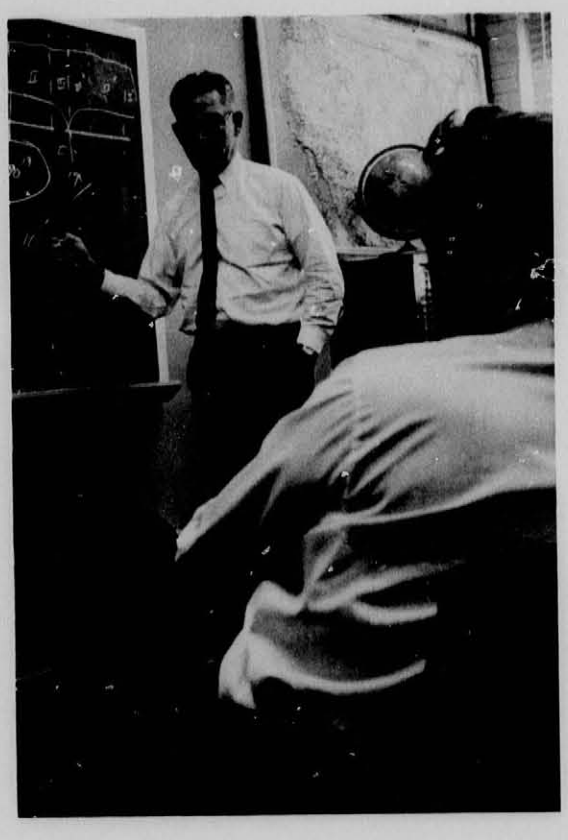
SPECIAL STUDENTS

A limited number of undergraduates who wish to carry on special studies and who are not degree candidates may enroll as Special Students. The Admissions Office will act on the application after seeking approval of the individual instructors if there is doubt about the applicant's ability to take the particular subjects for which application has been made or if there is a question of space in these subjects. 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.


PDP-4

GRADUATE EDUCATION: *Creativity and Intellectual Independence* 3.



Study and research for advanced degrees have held a prominent place at M.I.T. for more than 60 years.

The Graduate School seeks to promote the best environment for advanced study and for intimate association among creative workers, both faculty and students, as a community of scholars, and to extend the boundaries of knowledge in their fields of study.

Through the Graduate School the departments collaborate to establish over-all requirements for admission, for character and quality of programs, and for degrees. Each student's program is guided by a department and its faculty in accord with these over-all standards.

Of first importance to any graduate school is the quality and productivity of its faculty. 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 each faculty member. Satisfaction in his work and in his association with students characterizes the effective teacher. M.I.T. is proud of its Faculty as judged by these criteria.

An outstanding characteristic, indeed a major asset, 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.

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 intellectual and humanistic horizons, producing new orientations, and developing growth in intellectual courage and in depth of understanding and social responsibility. 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 also closely associated with the ability to organize and express

important ideas in clear and simple terms. Thus 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 offer the student professional assignments 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.

For almost 50 years the Institute has consistently awarded the largest number of Master's and doctor's degrees in engineering in the nation, and in recent years M.I.T. has ranked at or very near the top in doctoral output in the physical sciences and mathematics. In addition, more recent programs in the life sciences, social sciences and humanities, architecture and city planning, and management have now assumed an integral role in the Graduate School of the Institute. Enrollment of Regular Graduate Students now stands at over 3,300. About 1,200 students enter the Graduate School each year, more than 900 of them coming to M.I.T. with baccalaureate degrees from about 200 other American colleges and universities. Some 70 foreign countries and more than 100 foreign universities are typically represented among the 700 foreign students enrolled in the Graduate School.



Resources for Graduate Study

Extensive resources for graduate study have developed naturally at M.I.T. from a long tradition of emphasis on contributions to new knowledge in fields of the Institute's interest. M.I.T.'s unique productivity of advanced degrees is the result of these pioneering interests of its Faculty that have generated support and indeed demand for advanced research. The wealth and diversity of teaching and research resources, described in this Catalogue, particularly by the individual departments in their respective sections, are a direct result. Graduate students — and, in appreciable numbers, undergraduate students — have central roles in all of the Institute's wide-ranging research activities; this participation is vital to the educational experience of both students and faculty and to the success of the research itself.







Interdisciplinary developments are especially vigorous and seminal. For example, in the Research Laboratory of Electronics graduate students and faculty from 12 departments, ranging from physics and life sciences to modern languages and economics, find an effective and congenial environment for their creative work. The rapidly evolving and productive interaction between science and engineering in the field of materials has generated both a standing interdepartmental committee for the guidance of doctoral work and a large interdisciplinary Center for Materials Science and Engineering. These and other interdepartmental teaching and research groups are described in Section 1.

Although most graduate students find their interests served by programs available within a single department, some elect to work in interdisciplinary fields which reach into two or more departments. In general, each graduate student's program can be designed to fulfill his own particular interests, subject to the general requirement that the field thus defined has scope and depth appropriate for an advanced degree regardless of whether or not its boundaries happen to fall within the scope of a single department. Most important, the faculty tend to regard departmental organization more as an administrative convenience than as a limit to the bounds of their scholarly interests.

The M.I.T. Libraries, described in detail in Section 1 of this Catalogue, provide a major resource for graduate study. They serve New England as a depository for unclassified reports of the Department of Defense, the Atomic Energy Commission, the National Aeronautics and Space Administration, and the Rand Corporation. The collections are notably strong in U.S.S.R. science and technology.

Another significant resource for graduate study is the cooperative cross-registration privilege with Harvard University, used comparably by graduate students of both institutions.

While the graduate student tends normally toward intensive preoccupation with his professional field, M.I.T. encourages breadth of experience as well. Leaders in many areas of knowledge give lectures and seminars on the campus, and in general these are open to all members of the Institute community.

The cultural and social life and recreational facilities of the M.I.T. campus, described in Section 1 of this Catalogue under the headings

Graduate

GRADUATE STUDENT ACTIVITIES

The Campus, Campus Activities, and Student Housing, are shared alike by undergraduate and graduate students. Concerts and dramatic performances are frequent on the campus, given by both Institute groups and professional performers; and Greater Boston is an outstanding cultural and intellectual center. Many graduate students take advantage of these exceptional opportunities for extending interests to new fields.

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, and graduate student entries are frequently successful in the intramural athletic program. The Nautical Association also welcomes graduate students.

Ashdown House for single men and women and Eastgate and Westgate apartments for married students, all described in Section 1 of this Catalogue, provide comfortable living accommodations, while Ashdown House also serves as a center for graduate student social life. A member of the Faculty serves as Master of the House, presiding informally over its activities.

Graduate Student Activities and Organizations

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 Ashdown House, of women graduate students, and of off-campus graduate residents. The Organization is concerned primarily with the general welfare of the graduate student body; encouraging social, athletic, cultural and other extracurricular activities; promoting closer relations between graduate students and faculty outside formal academic exercises; and giving voice to ideas and suggestions of graduate students.

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

Organization of the Graduate School

The administration of the Graduate School rests with the President and the Provost of the Institute; the Dean, Associate Dean, and Executive Officer of the Graduate School; and the Committee on Graduate School Policy, comprised of a faculty member from each department offering graduate degrees. The Institute Faculty is the same for undergraduate and graduate instruction.

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. The membership of the Committee on Graduate School Policy is listed with that of other faculty committees at the back of this Catalogue.

Because this catalogue statement is necessarily abridged, the *definitive* statement of organization, policies, and procedures of the Graduate School is given in the *Graduate School Manual*, a copy of which is sent with the registration material to each new graduate student. (Copies are also available from the Graduate School office and from departmental Graduate Registration Officers.) Each graduate student is expected to be familiar with this manual in order that he may know his privileges and his obligations and be familiar with operations of the School.

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 80)
Master of Science, S.M.
Master in Architecture, M.ARCH.
Master in City Planning, M.C.P.
Bachelor in Architecture, B.ARCH.

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, and these statements should be consulted for more definite information.

School of Architecture and Planning

Department of Architecture
ARCHITECTURE, Course IV

Department of City and Regional Planning
CITY AND REGIONAL PLANNING, Course XI

School of Engineering

Department of Aeronautics and Astronautics
AERONAUTICS AND ASTRONAUTICS, Course XVI
Aerodynamics and gas dynamics
Aeroelasticity
Aeronautical and astronautical engineering
Flight transportation
Fluid mechanics
Instrumentation
Instrumentation and automatic control
Materials engineering
Physics of fluids
Plasma physics and space sciences
Propulsion
Space mechanics
Structures
Vehicle design

Department of Chemical Engineering
CHEMICAL ENGINEERING, Course X
Applied chemistry
Biochemical engineering
Biomedical engineering
Catalysis and reactor engineering
Engineering operations
Fuel engineering
Materials
Materials engineering
Polymers and plastics
CHEMICAL ENGINEERING PRACTICE, Course X-A

Department of Civil Engineering
CIVIL ENGINEERING, Course I
Applied earth science
Civil engineering
Civil engineering systems
Construction and operations
Hydrodynamics
Materials
Materials engineering
Ocean engineering
Operations research
Planning and design
Soil mechanics
Structural mechanics
Structures
Transportation
Urban engineering
Urban systems analysis
Water resources

Department of Electrical Engineering
ELECTRICAL ENGINEERING, Course VI
Communications
Communications bioengineering
Computer science
Control engineering
Electrical engineering
Electrical science and engineering
Electromagnetic theory
Electronics
Energy processing
Materials engineering
Operations research
Quantum electronics
Solid-state electronics
Systems science

Department of Mechanical Engineering
MECHANICAL ENGINEERING, Course II
Materials engineering
Mechanical engineering

Department of Metallurgy and Materials Science
METALLURGY AND MATERIALS SCIENCE, Course III
Ceramics
Materials science
Metallurgy

Department of Naval Architecture and Marine Engineering
NAVAL ARCHITECTURE AND MARINE ENGINEERING, Course XIII
Acoustics
Hydrodynamics
Naval engineering
Ocean engineering
Operations research
Ship propulsion
Ship systems analysis
Structural mechanics
NAVAL CONSTRUCTION AND ENGINEERING (USN and USCG), Course XIII-A
SHIPPING AND SHIPBUILDING MANAGEMENT, Course XIII-B

Department of Nuclear Engineering
NUCLEAR ENGINEERING, Course XXII
Applied plasma physics
Fission technology

School of Humanities and Social Science

Department of Economics
ECONOMICS, Course XIV

Department of Humanities
HUMANITIES, Course XXI
Philosophy

Department of Modern Languages and Linguistics
LINGUISTICS, Course XXIII
Linguistics

Department of Political Science
POLITICAL SCIENCE, Course XVII

Department of Psychology
PSYCHOLOGY, Course IX
General experimental psychology
Physiological psychology
Social-developmental psychology

Alfred P. Sloan School of Management
MANAGEMENT, Course XV

Graduate

FIELDS OF GRADUATE STUDY

School of Science

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

Department of Chemistry
- CHEMISTRY, Course V
- Analytical chemistry
- Biophysical chemistry
- Chemical physics
- Geological chemistry
- Inorganic chemistry
- Nuclear chemistry
- Organic chemistry
- Physical chemistry

Department of Geology and Geophysics
- GEOLOGY AND GEOPHYSICS, Course XII
- Geochemistry
- Geology (classical geology, theoretical geology)
- Geophysics
- Oceanography
- Oceanography (Joint Program with Woods Hole Oceanographic Institution)

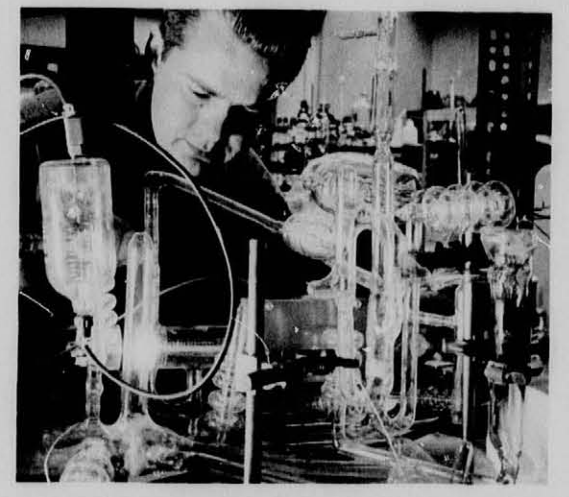
Department of Mathematics
- MATHEMATICS, Course XVIII

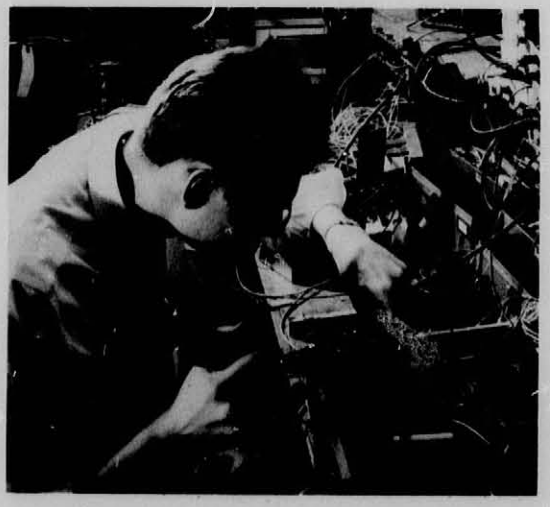
Department of Meteorology
- METEOROLOGY, Course XIX
- Oceanography
- Oceanography (Joint Program with Woods Hole Oceanographic Institution)

Department of Nutrition and Food Science
- NUTRITION AND FOOD SCIENCE, Course XX
- Biochemical engineering
- Clinical nutrition
- Food engineering
- Food science and technology
- Food toxicology
- Nutritional animal pathology
- Nutritional biochemistry and metabolism
- Oral biology

Department of Physics
- PHYSICS, Course VIII







Each graduate student is officially enrolled in one department or 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.

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 professional, social, and moral responsibility, along with specialized competence. To further this objective, graduate students may take electives offered by the School of Humanities and Social Science or at Harvard University.

INTERDEPARTMENTAL DOCTORAL PROGRAMS

Their interdisciplinary character is a notable feature of many recent developments in the physical and social sciences and engineering. Team research is one result of this; another result is that individual interests now frequently span several conventionally defined fields. Thus a number of graduate students now desire doctoral programs in fields that may be adequate in both scope and depth to meet doctoral standards but whose boundaries overlap substantially into two or more departments. In certain areas, such as materials engineering, instrumentation, and operations research, special continuing committees provide guidance. In other fields, interdepartmental doctoral programs are normally administered by *ad hoc* committees appointed for each case by the Dean of the Graduate School. Details of this procedure are found in the *Graduate School Manual.*

Admission to the Graduate School

The term Regular Graduate Student designates a student who 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, rarely, assistant professor. A student registered in a program of study leading to the simultaneous award of the degrees of Bachelor of Science and Master of Science or the Bachelor of Science 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 acceptable standing. His academic record and other credentials must indicate ability to accomplish satisfactorily an approved program of study and research. Admission to each department is by competition among the applicants for the places available.

Applicants are evaluated by the department in which they propose to register, on the basis of their prior performance and professional promise. These are evidenced by academic records, letters of evaluation from individuals familiar with the applicants' capabilities, and any other pertinent data furnished by the applicants. While previous high academic achievement does not guarantee admission, such achievement, or other unusually persuasive evidence of professional promise, is expected.

The engineering departments normally require students seeking a doctor's degree to qualify for a Master's degree first. At the time of registration the student decides, with the advice and consent of his department, for what degree he will register.

UNDERGRADUATE PREPARATION FOR ADVANCED DEGREES

In line with the Institute's conception of a broad undergraduate curriculum with emphasis in mathematics and science, most departments require the following preparation:

Mathematics. Preparation substantially equivalent to that provided by the Institute subjects 18.01, 18.02, and 18.034 (calculus and differential equations).

Physics. Preparation substantially equivalent to that provided by the Institute subjects 8.01, 8.02, and 8.03T (particles, Newtonian mechanics, relativity, oscillations and waves, electricity and magnetism).

Chemistry. Preparation substantially equivalent to that provided by Institute subject 5.01 (atomic theory, kinetic theory, chemical equilibrium, electrochemistry).

Some departments, however, require only a year of college mathematics and some only a year of natural science.

Humanities and Social Science. 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 made up 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 some of his deficiencies have been made up.

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

Students normally enter the Graduate School in September. However, in several of the departments suitable programs can be arranged for students entering in June, and each year a number of students are admitted in February.

Students wishing to enter in June or September should apply on the prescribed forms by February 15; candidates for admission in February should apply by December 1. However, applications submitted later by students who are not also candidates for financial aid may be considered if vacancies still exist.

Candidates for admission in June or September *who are also applicants for financial aid* should be careful to observe the following deadlines set by the departments for the receipt of applications:

Biology, Economics, Electrical Engineering, Physics and Political Science: February 1.

All other departments: February 15.

An applicant attending a college or university which is on the semester system should not wait until the end of the fall semester at his institution to submit an application for admission in June or September but should apply before the end of the term, submitting a transcript of his fall semester grades as soon as it is available.

Applications for admission should be submitted to the Director of Admissions, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139. A $10 application fee is required of all citizens of the United States or Canada and of all foreign students studying at United States or Canadian institutions. The fee should accompany the application form. Payment should be by check or money order, payable to Bursar, M.I.T. The fee is not required of a student who applies for readmission as a candidate for the same degree or for a higher graduate degree after a lapse of less than two years.

Notification about admission is sent as soon as action is taken (usually on or about April 1).

The admission of a student who is in his final year of work toward a Bachelor's degree is made conditional upon his subsequently providing evidence that he has been awarded the degree.

Correspondence concerning admission, including requests for application material, 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.

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 Regular Graduate Student, is judged by a departmental 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 Special Graduate Student is one whose intended program of study is essentially graduate in nature but who is not registered as a candidate for a degree; normally he will have received a Bachelor's degree. The applicant's qualifications for the specific program desired will normally be evaluated by the Chairman of the Graduate Committee of the department which best corresponds with his major area of interest. Admission is valid for only one term; a student must seek readmission each term to continue at the Institute. To be allowed to continue as a Special Graduate Student, he must receive grades satisfactory to the Committee on Graduate School Policy.

A Special Graduate Student who is subsequently admitted as a Regular Graduate Student may offer subjects, which he has completed, in partial fulfillment of requirements for an advanced degree. His department will determine to what extent such subjects are acceptable and whether he will receive residence credit for them.

Correspondence concerning admission as a Special Graduate Student should be addressed to the Director of Admissions, from whom appli-

cation material may be obtained. Applications must be filed at least two weeks prior to the beginning of the term.

ADMISSION OF FOREIGN STUDENTS TO THE GRADUATE SCHOOL

Applications for admission to the Graduate School from foreign students are welcomed. About one in five graduate students is from abroad. A foreign applicant is considered on the same basis as a United States applicant and the same requirements apply to him. Detailed information is contained in the *Application for Admission from Foreign Citizens* and a leaflet, *Information for Foreign Students*, which may be obtained from the Office of the Advisor to Foreign Students, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

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

Foreign graduate applicants whose native language is not English and whose schooling has not been predominantly in English must take the Test of English as a Foreign Language (TOEFL). This test is described in the paragraphs on Admission of Foreign Students (undergraduates) in Section 2 of this Catalogue.

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

GRADUATE RECORD EXAMINATIONS

Applicants for admission to graduate study in the Departments of Biology and Political Science are required to submit scores in the Aptitude Test and in the appropriate Advanced Test of the Graduate Record Examination. The Department of Biology will accept such test scores resulting from the advanced test in either chemistry, physics, or biology. All other departments recommend, but do not require, the submission of such scores, with the exception of the Sloan School. The Sloan School of Management requires applicant scores on the Admission Test for Graduate Study in Business (an aptitude test) only. Applicants are urged to consult with appropriate departments to confirm test requirements and recommendations.

Information as to time and location at which these tests are given can be obtained by writing to Graduate Record Examinations, Educational Testing Service, Box 955, Princeton, New Jersey 08540. Inquiries from students in western states should be addressed to 1947 Center Street, Berkeley, California 94704.

Registration

Registration material is available 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.

Cooperative Arrangement with Harvard University

A graduate student at M.I.T. or Harvard University 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 the other institution 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 full-time Special Graduate Students who are carried on the rolls of the Graduate School at M.I.T. This cooperative arrangement is applicable to the regular academic terms and not to the Summer Session.

Requests for registration under this cooperative arrangement should be confined to subjects which are not offered at the student's own





institution; if there is an apparent 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.

The procedures to be followed and deadlines to be observed by both M.I.T. and Harvard students wishing to enroll in subjects under this cooperative arrangement are given in the *Graduate School Manual.*

Cooperative Arrangement with Boston University

An arrangement analogous to that described above for Harvard has been made between the M.I.T. Departments of Economics and Political Science and the African Studies Program at Boston University. Details of the procedures to be followed, which are similar to those for Harvard-M.I.T. cross-registration, are given in the *Graduate School Manual.*

Cooperative Arrangement with Tufts University

A third cooperative arrangement exists between the M.I.T. Department of Nutrition and Food Science and the School of Dental Medicine at Tufts University. The program is restricted to specific graduate subjects at each institution, a list of which may be obtained from the Office of the Dean of the Graduate School. More complete information is given in the *Graduate School Manual.*

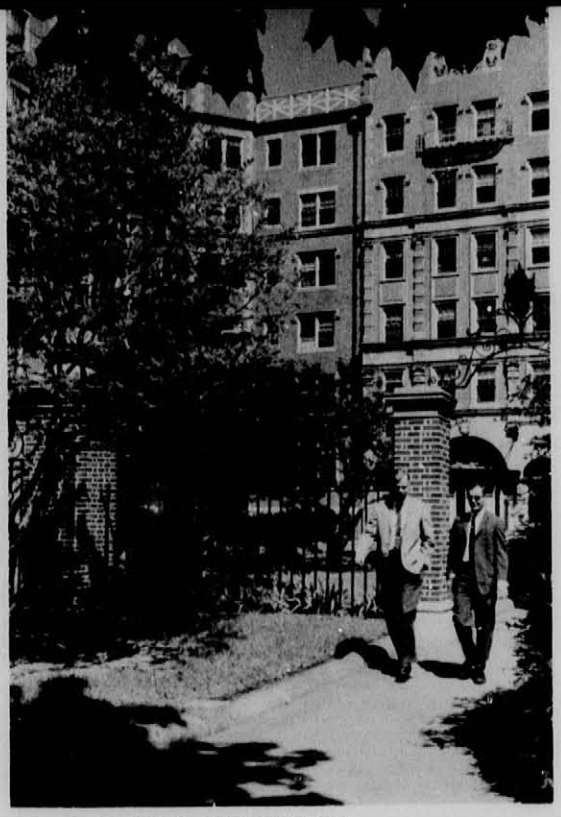
Medical Services and Requirements

Information concerning Medical Services and the requirement of a medical examination for *all* entering students, including graduate students, will be found in Section 1 of this Catalogue. Participation in the Institute's Health Insurance Program is required as a means of avoiding the serious financial burden experienced each year by a number of students as a result of prolonged illness or accident.

Military Service

The Office of the Graduate School counsels and assists enrolled and prospective (admitted) graduate students in their representations to Selective Service Boards and/or the various military services relative to classification, deferment, and delay and is prepared to help in every way possible. 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.

With regard to Selective Service, the Institute has taken the position that a graduate student, in good standing, who enters the armed forces will be readmitted to the Graduate School provided he reapplies within five years after leaving M.I.T.



THE AVERY ALLEN ASHDOWN HOUSE

The Committee on Graduate School Policy has further resolved that: A graduate student, in good standing, whose education is interrupted for reasons related to Selective Service will be readmitted irrespective of whether he enters the armed forces or does not serve because of moral or conscientious objection, provided he applies for readmission within five years after leaving M.I.T. Students are urged to keep abreast of such forthcoming developments through the Graduate School Office and their Selective Service Boards.

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.

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 chairman of the Committee on Graduate Students of the department in which he wishes to enroll.

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

THE DEGREE OF BACHELOR IN ARCHITECTURE

The graduate degree of Bachelor in Architecture is awarded upon the satisfactory completion of a program of study of at least 164 subject units approved by the Department of Architecture, of which 96 units must be in "A" subjects, and the completion of a thesis acceptable to the Department. ("A" subjects are those intended primarily for graduate students; they are indicated in the Descriptions of Subjects given at the back of this Catalogue.)

A student who has obtained the degree of Bachelor of Science in Art and Design at the Institute or an equivalent degree at another institution may attain the degree of Bachelor in Architecture in two years. A student who enters without previous experience in a department of architecture may take four years.

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.

Degree Requirements

The degrees Master of Science, Master in Architecture, and Master in City Planning are awarded upon the satisfactory completion of an approved program of study of at least 66 subject units, of which 42 units must be in "A" subjects, and the completion of an acceptable thesis.

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 34 units of "A" subjects and the 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 "The Undergraduate Programs" 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 two academic years beyond a baccalaureate in the same field.

The following Engineer degrees are awarded: 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.), and Ocean Engineer (OCEAN E.).

The requirement for such a degree is the satisfactory completion of a program of advanced study and research approved by the appropriate department of the School of Engineering. The minimum program consists of at least 162 subject units and the completion of an acceptable thesis. 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 Thesis for the Master's and Engineer Degrees

The caliber and scope of the Master's and Engineer theses are, in general, such as to require the equivalent of the full time of a student for at least a half of a term. Many theses may require a somewhat longer time. Every degree candidate working on a thesis is expected to register for the appropriate number of hours per week devoted to thesis in all periods during which his thesis research is actually in progress.

THE DOCTORATES

M.I.T. offers the degrees of Doctor of Science and Doctor of Philosophy interchangeably in branches of science and engineering, and the degree of Doctor of Philosophy alone in city and regional planning, economics, political science, biology, psychology, philosophy, linguistics, and management. 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 three basic requirements for a doctorate are:

1. Completion of a program of advanced study, including a general examination.
2. Demonstration of proficiency in modern foreign languages, as explained in detail below.
3. 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 Program of Advanced Study

The program of advanced study and research may be selected in any field approved by the department in which the student is enrolled. The thesis is in this same field. The program often comprises subject areas reaching into several departments. If the 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 in his field at such time and in such manner as his departmental or interdepartmental committee approves. This examination consists of both oral and written parts.

The Language Requirement

Each candidate for a doctorate must demonstrate to the Department of Modern Languages and Linguistics:

Either

1. Intermediate competence in speaking and reading one modern foreign language.

or

2. Ability to read and translate the scientific literature of his field of specialization from two modern foreign languages into English.

In all cases, the language or languages chosen must be acceptable to the department in which the student is enrolled; and must be languages in which there is important literature in the area of his specialization, or which will be necessary for doctoral field purposes. Accordingly, a student whose native language is other than English may expect acceptance of his native tongue as an approved language only if it meets these conditions.

In connection with the first option, the Department of Modern Languages and Linguistics will give transfer credit for language subjects with a speaking and reading stress taken at college through the intermediate level with a grade of C or better; in connection with the second option, for language subjects with a reading stress taken at college through the intermediate level with a grade of C or better, and also for graduate examinations of at least equal difficulty passed elsewhere by transfer students.

Examinations for competence in one language are oral and written. Ability to read and translate is tested by written examination. Written examinations in reading and translating French, German, Russian, and Spanish are given by the Department of Modern Languages and Linguistics four times a year on a Saturday in November, January, March, and May designated at the beginning of the term in question. Written examinations in other approved languages and all oral examinations are arranged individually upon request. A student who requests a written examination in French, German, Russian or Spanish at an unscheduled time, or in any other language at any time, is required to submit with his application a receipt from the Bursar indicating that he has paid a special fee of $30 for this purpose. *Any student who fails to appear for a predoctoral language examination is subject to a fine of $10.*

Every candidate for the doctorate is normally expected to complete the language requirement for the degree as set by the Graduate School and by his department no later than the beginning of his third year in residence.

The Thesis

The caliber 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 pertaining thereto is 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 research done *in absentia*, except under very special conditions and with specific prior approval by the Committee on Graduate School Policy. A full statement of policy on thesis research *in absentia* is given in the *Graduate School Manual*.

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.

Minor Requirement

The Institute believes that candidates for the doctor's degree should be aware of the context of their special field in the spectrum of human knowledge. Although there is no Institute requirement of a Minor for the doctor's degree, certain departments require that candidates take a number of subjects outside their major field. Further information concerning this and other departmental requirements may be obtained from the individual departments.

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. 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.

All thesis work must be done under the supervision of an authorized 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.

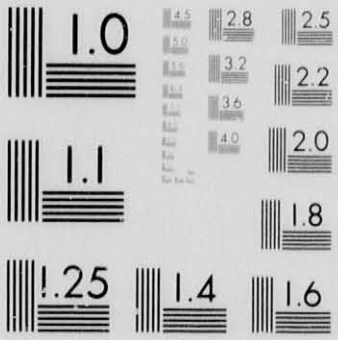
For the doctor's degree, the course of advanced study must be pursued under the direction of the Committee on Graduate School Policy for at least two academic years of full-time graduate work, including the research for and writing of a thesis, normally with residence credit. In the case of students who satisfy the Committee that they have successfully accomplished at another institution advanced work of a grade equal to that required at the Institute, the required period of residence may be reduced. In no case may the required period of residence be reduced to less than the equivalent of three full-time academic terms, not more than one of which may be a summer term.

Financial Assistance to Graduate Students

Financial support is available to graduate students from a variety of sources and in a variety of forms — fellowships, traineeships, scholarships, teaching and research assistantships, and loans. The Deferred Payment Plan, Installment Credit Plan, and student employment are available to all students, with the few exceptions stated in Section 1. Every prospective student is strongly urged to explore all the sources of aid available to him as he considers the means of financing his graduate education. For the majority of applicants for admission, expenses need not be a deterrent.

FELLOWSHIPS, TRAINEESHIPS, AND SCHOLARSHIPS

A fellowship or traineeship is a grant to a graduate student which covers his tuition and provides, in addition, a stipend to help defray his living expenses. In the context of the Graduate School, a scholarship is a grant which only covers, or helps to defray, tuition only. Awards are made on the basis of academic promise and financial need, and are intended solely to assist a student in the pursuit of his studies. No ser-



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vices are expected in return. Under Section 117 of the U.S. Internal Revenue Code of 1954, such grants, held by degree candidates, are not subject to income tax.

The Institute is fortunate to have received funds from individual donors and corporations which provide for the support of about 250 fellowships and scholarships each year; the funds which make these possible are listed in Appendix A of this Catalogue. In addition, many government agencies and foundations offer fellowships and other grants which they award either directly to outstanding students for use at institutions of their choice or to institutions for award by them to students. Fellowships available under these national programs, including fellowships and traineeships granted by national agencies for award by M.I.T., are summarized in the adjoining column. About 800 graduate students at M.I.T. have fellowships or other grants from national agencies for the academic year 1968–69.

Application for Fellowships, Traineeships, or Scholarships Administered by M.I.T.

A student may apply for any of the fellowships, traineeships, or scholarships administered by M.I.T., including those granted by national agencies and foundations for award by the Institute, by filing a single form entitled *Application for a Fellowship, Traineeship, or Scholarship in the Graduate School;* each applicant is automatically considered for all awards for which he is eligible. The form, which is obtainable from the M.I.T. Admissions Office, should be completed and returned to the Director of Admissions.

Applications for fellowship aid for the regular academic year, beginning with the fall term, must be filed by the previous February 1 in the case of students applying in economics, electrical engineering, physics, and psychology, and by February 15 in the case of other departments. Applications for fellowship aid filed after these dates are considered only as funds are available. An application for aid from a prospective student will not be considered unless he has also filed a completed Application for Admission. Final action on applications is taken on the recommendation of departments to the Committee on Graduate School Policy at the end of March after the announcement of awards to applicants by the national agencies and foundations under their national competitive programs.

(text continues on page 84)

NATIONAL FELLOWSHIPS FOR GRADUATE STUDY

Atomic Energy Commission

Over 200 fellowships awarded annually by the Oak Ridge Institute of Nuclear Studies for U.S. graduate students in nuclear science and engineering. Twelve months' tuition plus $2,400 to $2,800 and dependency allowances. Renewable. Apply to the AEC Fellowship Office, University Relations Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee 37831.

Danforth Foundation

About 120 fellowships annually to male students graduating from U.S. colleges who seek to become teachers. Tuition plus $1,800 for a single student, $2,200 if married, with dependency allowances for up to three children. Renewable for four years of study. Nomination in early fall by the student's undergraduate college to the Danforth Foundation, 607 North Grand Boulevard, St. Louis, Missouri 63103.

National Defense Education Act, Title IV

Fellowships granted by the U.S. Department of Health, Education, and Welfare for award by M.I.T. to graduate students in new, expanded, or ongoing programs of study. Tuition plus $2,000 to $2,400 for nine months and summer and dependency allowances. Tenable for three years. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T. M.I.T. was allotted 36 new NDEA Fellowships for the academic year 1968–69.

National Institutes of Health

A large program of fellowships for U.S. graduate students in the medical sciences and areas of the biological, physical, and behavioral sciences related to health, environmental health, and other health-oriented fields. Twelve months' tuition plus $2,400 to $2,800 and dependency allowances. Renewable. Application to the Career Development Review Branch, Division of Research Grants, National Institutes of Health, Bethesda, Maryland 20014.

Grants of the National Institutes of Health provide traineeships for award by M.I.T. to U.S. graduate students in the medical sciences and health-related fields. Tuition plus a stipend determined by the department handling the grant, comparable to the stipend from a NIH fellowship. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T.

National Science Foundation

About 2,500 fellowships awarded annually to U.S. graduate students for study in the mathematical, physical, medical, biological, and engineering sciences, anthropology, economics, geography, the history and philosophy of science, linguistics, political science, psychology, and sociology. Twelve months' tuition plus $2,400 to $2,800 stipend and dependency allowances. Awarded for one or two years; renewable. Application in the fall to the National Science Foundation, Washington, D.C. 20550. Watch for NSF announcements on dates.

Grants of the National Science Foundation provided for 151 traineeships in the same fields at M.I.T. in 1968–69 as part of a national traineeship program. Financial terms identical with those of the graduate fellowships. Renewable. Application on standard M.I.T. fellowship form to the student's prospective department at M.I.T.

Woodrow Wilson National Fellowship Foundation

One hundred fellowships to first-year graduate students, primarily to candidates in the humanities and social sciences but science and mathematics majors with a clear interest in teaching careers may be chosen. U.S. and Canadian citizens only. Nine months' tuition plus stipend of $1,800 and dependency allowances. Not renewable. Nomination in early fall by a faculty member to the Chairman of the appropriate Regional Committee. For information, write the Woodrow Wilson National Fellowship Foundation, Box 642, Princeton, New Jersey. (This program may be modified in the near future.)

Other

These include the Federal Housing and Urban Development National Fellowship Program, NDFL Traineeships, NASA International Fellowships, Department of the Interior Traineeships, NIH Air Pollution Fellowships, and the Hertz Foundation Fellowship Program, for support in certain fields of graduate study, and based on M.I.T. nominations. Contact appropriate agency or see Graduate School Office for details. Also consult the Graduate School Office publication *Financial Support for Graduate Students*.

A student who individually secures such award is not considered further for an award by M.I.T.

Resident tutorial positions in undergraduate Institute Houses and fraternity houses provide room and board. Application from students who have completed at least one graduate year at M.I.T. or who have been M.I.T. undergraduates may be made to the Dean of Student Affairs.

Award of Fellowships, Traineeships, and Scholarships

Notices of award by the Institute are mailed for delivery by the end of March. In accordance with a resolution of the Council of Graduate Schools in the United States, to which over 180 graduate schools have signified their assent, a student has until April 15 to accept or decline an offer. If a student does not reply to an offer shortly after this date it may be cancelled.

Every student holding a fellowship, traineeship, or scholarship for graduate study at the Institute is expected to register as a regularly enrolled student for the period of the award, pursuing a full program of studies (or the accepted equivalent in the case of a teaching or research assistant). If a student with an award which is paid to him through M.I.T. withdraws from the Institute before his tenure expires, the Institute will consider him to have relinquished the award, and he will be required to make such refund of any sum already paid to him as the Committee on Graduate School Policy deems appropriate. An award may also be terminated for failure to maintain a satisfactory standard of scholarship.

TEACHING ASSISTANTSHIPS

About 600 graduate students are appointed each year as instructors or teaching assistants. They assist the faculty in grading undergraduate quizzes, instructing in the classroom and laboratory, and conducting tutorials. They receive salaries which, after taxes, are roughly comparable to fellowship stipends. They are generally awarded scholarships to cover their tuition.

After four years or more of intensive study at the undergraduate level, many students enjoy the new view of their subject afforded by a teaching assignment. The departments consider seriously the benefits of a teaching assistantship as a preparation for a career in university teaching, and the Institute offers a prize each year — the Goodwin Medal — for conspicuously effective teaching by a graduate student.

A student accepting a teaching assistantship typically does not prolong his time to the doctor's degree. The average time taken by students who have held assistantships is not significantly different from the time taken by students who have held fellowships during the same period.

The units for which an instructor or teaching assistant may register as a student are determined by his department in the light of his assistantship duties, his compensation being adjusted accordingly.

Appointments to teaching assistantships are made upon recommendation of the head of a department. A student who wishes to be considered for a teaching appointment should write to his prospective department; such applications from new students will be considered only after an Application for Admission to the Graduate School has been filed with the Admissions Office.

RESEARCH ASSISTANTSHIPS

About 1,000 graduate students at M.I.T. each year hold appointments as research assistants. They assist members of the Faculty in the research projects which are a major characteristic of the academic life of the Institute and a prime reason for its vitality. It is a policy of the Institute only to accept such projects as will be in keeping with its educational objectives.

Research assistants receive stipends which are intended to be comparable in attractiveness, after payment of tuition, with fellowship stipends. In so far as the duties of a research assistant relate to the thesis work which he is required to perform for his degree, his salary is normally considered the equivalent of a fellowship stipend for tax purposes, and taxes are not withheld. (A research assistant's stipend may be found liable to tax in an individual case.)

The units for which a research assistant may register are determined by his department in the light of his duties and his program of study, his stipend being adjusted accordingly.

Many students prize the opportunity a research assistantship gives them to participate as junior colleagues of the faculty in an ongoing research project. The experience enlivens their Course work and frequently determines their choice of thesis topic. In many cases a research assistant's thesis work parallels closely his contribution to the project.

Appointments to research assistantships are

made in the same manner as appointments to teaching assistantships.

GRADUATE ASSISTANTSHIPS

Some departments also appoint graduate students to junior academic staff positions as graduate assistants. The appointment is a flexible one which allows a department to vary a student's duties as he progresses in his academic work; at one point he may be engaged in teaching, at another in research. A graduate assistant is normally compensated in the same manner as a teaching assistant if he is primarily engaged in teaching and in the same manner as a research assistant if he is primarily employed in research. Appointments are made in the same manner as appointments to research and teaching assistantships.

STUDENT LOAN FUNDS

The Institute administers a considerable loan program under which financial assistance is available to students in all fields of study. A student may borrow to support a reasonable budget for which he has insufficient resources. To be considered, a student must submit a budget giving evidence of his need. Full details about loan funds will be found in Appendix A. Application should be made to the Director of Student Aid, from whom forms may be obtained.

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.

A graduate student may not interrupt his academic program to accept a staff appointment in the Division of Sponsored Research (D.S.R.), the Instrumentation Laboratory, or Lincoln Laboratory either during the academic year or during the summer unless he has the approval of his Department Head and of the appropriate Academic Dean and unless his work as an employee is unrelated to his thesis research. 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.

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.

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" in Section 1 of this Catalogue.)

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. To undertake general doctor's or comprehensive Engineer degree examinations;
2. To undertake language examinations prescribed for advanced degrees;
3. To complete thesis presentation with or without thesis examination, and either with or without simultaneous enrollment on a degree list;
4. To enroll on a degree list and in 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.



SCHOOL OF ARCHITECTURE AND PLANNING 4.

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

Architecture and planning involve the art of design as applied to the built-in physical environment. Architects work with structures and spaces at a scale enabling them to create intense visual experiences and requiring close control over the means of construction. Planners work in the larger framework of urban form; their conceptions are less directly experienced in visual terms, while their technology leans more heavily on the social sciences.

Both professions have traditions extending back throughout recorded history, but twentieth-century life poses more difficult challenges and offers greater scope than in the past. Planning especially is growing to a new importance in recognition of the urgency of the environmental problems of modern cities. The information and the technical methods for designing and executing solutions in both architecture and planning stem largely from the scientific revolution, and the School therefore benefits enormously from its placement in a scientific university.

Yet the performance of a well-designed environment is not entirely, perhaps not even principally, measurable by scientific methods. The education of the designer must be concerned in large measure with a search for the definition of these less tangible goals. Excellence in design embraces in its stride economy, function, and stability and then goes on toward its humanistic mission and toward an elegance of expression that characterizes highest creativity in any field.

Reinforcing the importance of cultural and aesthetic insights, an important section in the School is concerned with a broad perspective of the visual arts. This includes the scholarly study of the history and criticism of art and architecture as well as studio experiences in several forms of direct visual expression. The presence of this nucleus attracts students from every part of the Institute and offers possibilities for undergraduate concentration in the visual arts.

The overriding challenge of architecture and planning today is not in individual, isolated works of design; it is in bending the total environment to make a cohesive and satisfying background for modern urban life, in shaping individual creativity to fit into an ongoing social process of great complexity and dynamism. That is why these professions are now seeking to understand all the forces that are brought to bear in giving form to the physical environment.

LAWRENCE B. ANDERSON

Architecture

DEPARTMENT OF ARCHITECTURE

Department of Architecture

DONLYN LYNDON, M.F.A.
Professor of Architecture; Head of the Department

LAWRENCE BERNHART ANDERSON, M.ARCH.
Professor of Architecture;
Dean of the School of Architecture and Planning

HORACIO CAMINOS, ARQ.
Professor of Architecture

EDUARDO FERNANDO CATALANO, M.ARCH.
Professor of Architecture

ALBERT GEORGE HENRY DIETZ, SC.D.
Professor of Building Engineering

GYORGY KEPES, M.A.
Professor of Visual Design;
Director of the Center for Advanced Visual Studies

ELIAHU EDUARD TRAUM, SC.D.
Professor of Structures (Visiting)

MINOR WHITE
Professor of Photography (Visiting)

WACLAW PIOTR ZALEWSKI, D.TECH.SCI.
Professor of Structures

WAYNE VESTI ANDERSEN, PH.D.
Associate Professor of the History of Art;
Director of Exhibitions

WILLIAM HOSKINS BROWN, M.ARCH.
Associate Professor of Architecture

RICHARD FILIPOWSKI, B.A.
Associate Professor of Visual Design

YUSING YIU-SING JUNG, M.ARCH.
Associate Professor of Architecture (Visiting)

WILLIAM JAMES LEMESSURIER, A.B., S.M. *(Absent)*
Associate Professor of Structures

KARL LINN, M.A.
Associate Professor of Architecture and City Planning

HENRY ARMAND MILLON, PH.D.
Associate Professor of the History of Architecture

JOHN RANDOLPH MYER, B.ARCH.
Associate Professor of Architecture

ROBERT BRADFORD NEWMAN, SC.D.
Associate Professor of Architecture

ROBERT ORMEROD PREUSSER
Associate Professor of Visual Design

MAURICE KEITH SMITH, B.ARCH.
Associate Professor of Architecture

CHESTER LEE SPRAGUE, M.ARCH.
Associate Professor of Architecture

STANFORD ANDERSON, M.A.
Assistant Professor of the History of Architecture

ROBERT GOODMAN, B.ARCH.
Assistant Professor of Architecture

LEON BENNETT GROISSER, A.B., B.S., M.B.A.
Assistant Professor of Structures

ROSALIND EPSTEIN KRAUSS, M.A.
Assistant Professor of the History of Art

NICHOLAS PETER NEGROPONTE, M.ARCH.
Assistant Professor of Architecture

GEORGE CULBRETH THOMAS, II, M.F.A.
Assistant Professor of Photography

Lecturer

PATRICK MORREAU, B.A.

Instructors

JONATHAN WILLIAM GREEN, M.A.
JOHN AMES STEFFIAN, M.ARCH.

Technical Instructor

NISHAN BICHAJIAN

Research Associates

EDWARD BLAIR ALLEN, M.ARCH.
IGNACIO HIPOLITO GARABIETA-ORUETA, DIPL.
MARVIN EDWARD GOODY, M.ARCH., M.C.P.
TIMOTHY EDWARD JOHNSON, S.M.
ROBERT JOSEPH PELLETIER, B.ARCH., BLDG.E.

Professors Emeriti

PIETRO BELLUSCHI, DOTT.ING., LL.D., SC.D., D.F.A.
Professor of Architecture, Emeritus;
Dean of the School of Architecture and Planning, Emeritus

HERBERT LYNES BECKWITH, M.ARCH.
Professor of Architecture, Emeritus

HENRY LATIMER SEAVER, A.M.
Professor of History, Emeritus

Architecture is an art; only creative insight may achieve it. 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 CURRICULA

Architecture (Course IV)

Four undergraduate programs of concentration are offered by the Department of Architecture: Program 1 — Architecture; Program 2 — City Planning; Program 3 — Visual Design; and Program 4 — History, Theory and Criticism of Visual Arts. These four programs are designed to provide within the general educational objectives of the Institute a concentration in aspects of the design of the physical environment. Selection of one of these programs will prepare a student for graduate professional study in the corresponding area.

All four programs lead to the degree of Bachelor of Science in Art and Design. The student should choose his program of concentration not later than the end of the second year.

Students in the Department of Architecture may, upon consultation with a Faculty Advisor, exercise flexibility in scheduling completion of General Institute Requirements. Deferment of a portion of the General Institute Requirements in the first year will allow those who so choose to elect appropriate subjects of professional interest within the Department of Architecture and other departments of the Institute. It should be emphasized, however, that any program of studies that involves postponing first-year physics and mathematics will limit the possibilities of easy transfer from the Department of Architecture to those departments of the Institute that, within a four-year sequence, presuppose the completion of most of the science and mathematics portions of the General Institute Requirements by the end of the sophomore year. In addition, some advanced subjects in departments other than Architecture presume the knowledge acquired in fulfilling General Institute Requirements. Registration in subjects of interest in those departments may be precluded or postponed by deferment of General Institute Requirements. Within the architecture programs, the subject matter treated in first-year physics and mathematics is necessary to undertake the required subjects Structures I (4.30) and Engineering Materials (1.02).

The curricula requirements are as follows:

					Total units
GENERAL INSTITUTE REQUIREMENTS					
	Specific Science Subjects				
5.01	CHEMISTRY	5	0	7	
8.01	PHYSICS I	5	0	7	
8.02	PHYSICS II	5	0	7	
18.01	CALCULUS	4	0	8	
18.02	CALCULUS	4	0	8	
					60
	Humanities and Social Science Subjects[1]				
	(See pages 50–55)				**68**
					128
	Science Distribution Requirement				
	The Science Distribution Requirement will be satisfied by 1.02 and 4.30 which are required in each of the Departmental Programs given below, plus appropriate subjects (see pages 48–49) totaling				**12**
	Laboratory Requirement				
	At least 12 units *(see page 49)*				**12**
					152

[1] ECONOMIC PRINCIPLES I (14.01) is required in all programs as an upperclass Humanities subject. In the following programs the subjects indicated may *not* be used to satisfy the upperclass Humanities and Social Science Requirement. *Program 1:* Field 9 — 9.00; Field 10 — 4.601, 4.61, 4.62, 4.63, 4.64. *Program 2:* Field 7 — 17.21, 17.22; Field 9 — 9.00; Field 10 — 4.601. *Programs 3 and 4:* Field 9 — 9.00; Field 10 — all subjects.

1. ARCHITECTURE PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS					
	(Including the Science Distribution and Laboratory Requirement, as specified above)				**152**
DEPARTMENTAL PROGRAM					
	Required Subjects				
1.02	ENGINEERING MATERIALS	3	3	6	
4.031	FORM AND DESIGN I	2	4	6	
4.032	FORM AND DESIGN II	2	4	6	
4.30	STRUCTURES I	3	3	6	
4.402	BUILDING PROCESS	3	3	6	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	5	
4.701J	ARCHITECTURAL COMMUNICATION	4	2	2	
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION	2	2	2	
9.00	INTRODUCTORY PSYCHOLOGY	3	0	5	
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6	

(continued)

Architecture

DEPARTMENT OF ARCHITECTURE

Required Subjects *(continued)*

4.121	ARCHITECTURAL DESIGN	2	5	5	
4.122	ARCHITECTURAL DESIGN	2	5	5	
4.131	ARCHITECTURAL DESIGN	0	6	6	
4.132	ARCHITECTURAL DESIGN	0	6	6	
4.31	STRUCTURES II	2	2	4	
4.32	STRUCTURES III	2	2	4	
					162

Restricted Electives

Two of the following subjects:

4.61	ARCHITECTURE IN THE ANCIENT WORLD	3	0	5	
4.62	ARCHITECTURE 1400–1750	3	0	5	
4.63	ARCHITECTURE IN THE MIDDLE AGES	3	0	5	
4.64	ARCHITECTURE FROM 1750 TO THE PRESENT	3	0	5	
					16

Unrestricted Electives **36**

Total units required for the S.B. degree **366**

2. CITY PLANNING PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS		
	(Including the Science Distribution and Laboratory Requirement, as specified above)	**152**
DEPARTMENTAL PROGRAM		
	Required Subjects	

1.02	ENGINEERING MATERIALS	3	3	6	
4.031	FORM AND DESIGN I	2	4	6	
4.032	FORM AND DESIGN II	2	4	6	
4.30	STRUCTURES I	3	3	6	
4.402	BUILDING PROCESS	3	3	6	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	5	
4.701J	ARCHITECTURAL COMMUNICATION	4	2	2	
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION	2	2	2	
9.00	INTRODUCTORY PSYCHOLOGY	3	0	5	
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6	
					98

Restricted Electives

77 units to be chosen from the following:

4.67	HISTORY OF URBAN FORM	3	0	5	
11.01T	COMMUNITY PLANNING DESIGN	Arr.			
11.11	COMPONENTS OF THE URBAN ENVIRONMENT	3	0	6	
11.15	SITE PLANNING	1	2	5	
11.60	CITY STRUCTURE AND ECONOMIC DEVELOPMENT	2	0	6	
11.90	METHODS OF RESEARCH IN CITY PLANNING	2	0	6	
17.21	AMERICAN POLITICAL PROCESS	3	0	5	
17.22	STRUCTURE OF URBAN LIFE	2	4	10	
					77

Unrestricted Electives **36**

Total units required for the S.B. degree **363**

3. VISUAL DESIGN PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS		
	(Including the Science Distribution and Laboratory Requirement, as specified above)	**152**
DEPARTMENTAL PROGRAM		
	Required Subjects	

1.02	ENGINEERING MATERIALS	3	3	6	
4.031	FORM AND DESIGN I	2	4	6	
4.032	FORM AND DESIGN II	2	4	6	
4.30	STRUCTURES I	3	3	6	
4.402	BUILDING PROCESS	3	3	6	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	5	
4.602	INTRODUCTION TO MODERN ART	3	0	5	
4.701J	ARCHITECTURAL COMMUNICATION	4	2	2	
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION	2	2	2	
9.00	INTRODUCTORY PSYCHOLOGY	3	0	5	
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6	
					106

Restricted Electives

	One eight-unit subject[1] in art history, in addition to 4.601 and 4.602				8

60 units of visual design subjects to be chosen from the following:

4.013	GRAPHIC COMPOSITION	2	4	6	
4.022	VISUAL DESIGN PROBLEMS II	2	6	0	
4.023	VISUAL DESIGN PROJECTS	2	4	6	
4.033	FORM AND COLOR I	2	0	4	
4.034	FORM AND COLOR II	2	4	6	
4.041	LIGHT AND COLOR I	2	4	6	
4.051T	CREATIVE PHOTOGRAPHY I	2	6	0	
4.054	ADVANCED PHOTOGRAPHY	2	4	6	
4.071	PAINTING	2	6	0	
4.081	PLASTIC COMPOSITION	2	4	6	
					68

Unrestricted Electives **36**

Total units required for the S.B. degree **362**

[1] Subject to be chosen in consultation with the student's Faculty Counselor.

4. HISTORY, THEORY, AND CRITICISM OF ART AND ARCHITECTURE PROGRAM CURRICULUM

		Total units
GENERAL INSTITUTE REQUIREMENTS		
	(Including the Science Distribution and Laboratory Requirement, as specified above)	**152**
DEPARTMENTAL PROGRAM		
	Required Subjects	

1.02	ENGINEERING MATERIALS	3	3	6	
4.031	FORM AND DESIGN I	2	4	6	
4.032	FORM AND DESIGN II	2	4	6	
4.30	STRUCTURES I	3	3	6	
4.402	BUILDING PROCESS	3	3	6	
4.601	TOPICAL STUDIES IN THE HISTORY OF ART	3	0	5	
4.701J	ARCHITECTURAL COMMUNICATION	4	2	2	
6.47	INTRODUCTION TO AUTOMATIC COMPUTATION	2	2	2	
9.00	INTRODUCTORY PSYCHOLOGY	3	0	5	
11.50	URBAN SOCIAL STRUCTURE AND PROCESS	2	0	6	
4.602	INTRODUCTION TO MODERN ART	3	0	5	
4.681	THEORY AND METHOD IN THE HISTORY OF ART AND ARCHITECTURE	3	0	5	
					114

Restricted Electives

	The student may elect to concentrate in either History of Painting and Sculpture (Group a) or History of Architecture (Group b). A reading knowledge of French or German is required by the end of the junior year.[1]	
	Design subjects chosen from the subjects listed in Programs 1 and 3,[2] totaling at least	24

	A minimum of 40 units chosen from Group a and Group b, at least one subject to be selected from the alternate group			40	64
	Group a. History of Painting and Sculpture				
4.603	PAINTING AND SCULPTURE IN THE MIDDLE OF THE NINETEENTH CENTURY	3	0	5	
4.604	MODERN ART FROM POST-IMPRESSIONISM TO CUBISM	3	0	5	
4.605	PAINTING IN THE TWENTIETH CENTURY	3	0	5	
4.606	SCULPTURE IN THE TWENTIETH CENTURY	3	0	5	
4.641	MODERN ARCHITECTURE IN GERMANY FROM 1895 TO THE BAUHAUS	3	0	5	
	LANGUAGE[1]	4	0	8	
	Group b. History of Architecture				
4.61	ARCHITECTURE IN THE ANCIENT WORLD	3	0	5	
4.62	ARCHITECTURE 1400–1750	3	0	5	
4.621	ORIGINS OF CONTEMPORARY ARCHITECTURE IN THE EIGHTEENTH CENTURY	3	0	5	
4.63	ARCHITECTURE IN THE MIDDLE AGES	3	0	5	
4.64	ARCHITECTURE FROM 1750 TO THE PRESENT	3	0	5	
4.641	MODERN ARCHITECTURE IN GERMANY FROM 1895 TO THE BAUHAUS	3	0	5	
4.65	STUDIES TOWARD A THEORY OF ARCHITECTURE	3	0	5	
4.66	CRITICISM OF ARCHITECTURE	3	0	5	
4.67	HISTORY OF URBAN FORM	3	0	5	
21.454	[3]NEAR EASTERN ARCHAEOLOGY: THE FOUNDATIONS OF CIVILIZATION	3	0	5	
	LANGUAGE[1]	4	0	8	
	Unrestricted Electives				36
	Total units required for the S.B. degree				366

[1] Any student who demonstrates to his Faculty Counselor his ability to read art historical literature in either French or German will have satisfied this requirement and need not include language in his elective program.

[2] Subjects are to be chosen in consultation with the Faculty Counselor. The Department recommends that students concentrating in History of Architecture elect 4.121 and 4.122 to fulfill the design requirement.

[3] 21.454, if taken as elective, may not be used in the Humanities Program.

GRADUATE STUDY IN ARCHITECTURE

The Department offers graduate study programs at two levels: Bachelor in Architecture and Master in Architecture. B.Arch. is the degree awarded to students who complete a program, accredited by the profession, that is an essential step toward licensure for architectural practice. M.Arch. is a second professional degree awarded to students who extend their studies beyond the B.Arch. Both programs are designed as preparation for practice, although they may also attract students preparing for teaching, writing, or research.

ENTRANCE REQUIREMENTS FOR GRADUATE STUDY

Undergraduate preparation in architecture usually differs from that leading to advanced studies for scientific and engineering degrees. The following requirements are substituted for those in Section 3 of this Catalogue.

Mathematics and Science. Four semester subjects at college level in mathematics and/or the physical sciences.

Humanities. Six semester subjects in the humanities and/or the social sciences.

Professional Preparation. For the Bachelor in Architecture program: no professional preparation is required for admission. A Bachelor's degree or equivalent with a high academic standing from a recognized institution is required. When credit has been received for professional subjects taken elsewhere, advanced credit may be allowed upon evaluation and comparison with similar subjects at M.I.T. M.I.T. students who have completed the architecture program leading to the S.B. in Art Design, upon admittance, will have completed the equivalent of two years of professional preparation in architecture. For the Master in Architecture program: completion of the curriculum for the first professional degree in architecture in a department or school of architecture of recognized standing.

The Graduate Degrees

BACHELOR IN ARCHITECTURE

The degree of Bachelor in Architecture is awarded upon the satisfactory completion of an approved program of at least 164 units, of which 96 units must be in "A" subjects, and an acceptable thesis. Completion ordinarily requires two years of residence beyond the Institute's undergraduate degree of Bachelor of Science in Art and Design.

A substantial number of candidates are admitted with a Bachelor's degree from other institutions; those who have not yet studied in a department of architecture will usually require four years of residence to fulfill the requirements for the B.Arch. degree.

MASTER IN ARCHITECTURE

This program, open only to students who have already earned the first professional degree, is designed to promote study in depth; candidates with degrees from other institutions will be required to be in residence for two academic years, and to complete approved programs substantially greater than the minimal requirements stated below. Candidates with the Institute's degree of B.Arch., having already completed 96 units of "A" subjects, can fulfill the requirements for the degree M.Arch. upon the satisfactory completion of the following additional requirements: an approved program of 66 units, of which 42 units must be in "A" subjects including one term of architectural design, and an acceptable thesis.

Architecture

DEPARTMENT OF CITY AND REGIONAL PLANNING

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, Emeritus; Senior Lecturer
ROLAND BRADFORD GREELEY, M.C.P.
Professor of Regional Planning; Director of Admissions

KEVIN ANDREW LYNCH, B.C.P. (*Absent*)
Professor of City Planning
FRANK ISAAC MICHELMAN
Professor of Law (Visiting)
JEAN PAELINCK, LL.D.
Professor of Economics
LLOYD RODWIN, PH.D
Professor of Land Economics;
Chairman of the Faculty Committee,
Joint Center for Urban Studies of M.I.T. and Harvard
JEROME ROTHENBERG, PH.D.
Professor of Economics
DONALD ALLEN SCHON, PH.D.
Professor of Urban Studies (Visiting)
AARON FLEISHER, SC.D.
Associate Professor of Urban and Regional Studies
ROBERT M. FOGELSON
Associate Professor of History and City Planning
BERNARD JOEL FRIEDEN, PH.D.
Associate Professor of City Planning
KARL LINN, M.A.
Associate Professor of Architecture and City Planning
STEPHEN MCKINLEY CARR, M. ARCH.
Assistant Professor of Urban Design
LANGLEY CARLETON KEYES, PH.D.
Assistant Professor of City Planning
DANIEL WEISBERG, B.S.
Assistant Professor of Real Estate Economics (Visiting)

Lecturers

ALEXANDER GANZ, B.A.
PHILIP BARNARD HERR, M.C.P.
LISA REDFIELD PEATTIE, M.A.
MARY C. POTTER, PH.D.
JOHN F. C. TURNER, DIPL.ARCH.
ROBERT S. WEISS, PH.D. (*Visiting*)

Instructors

MICHAEL DAN APPLEBY, B.A.
WREN MEYER MCMAINS, S.B.

Professor Emeritus

FREDERICK JOHNSTONE ADAMS, B.ARCH.
Professor of City Planning, Emeritus; Senior Lecturer

City planning has long been concerned with our large-scale physical environment and its interaction with our urban society. The field is moving from a focus upon the public guidance and control of the physical form of communities and of limited aspects of their environmental quality to a broader concern with issues of urban and regional development such as poverty, race, education, economic development, and the distribution of power. Research and action is focusing on questions such as the relation of social and economic planning to physical planning; the interaction of the spatial environment with the behavior, attitudes, and satisfactions of the user; the formulation of public policies for the management and programming of urban and regional development and redevelopment; advances in methods of transportation and communication; the problems of planning in developing regions; the collection and analysis of urban data; the technical process of large-scale design; and the problems of political participation in planning and development.

The Department of City and Regional Planning seeks to increase understanding of these issues and problems, and to train professionals and scholars who can act as advisors, managers, or advocates in the processes of urban and regional development.

UNDERGRADUATE PREPARATION AT M.I.T.

The Department does not offer an undergraduate degree.

Undergraduates in the Department of Architecture who choose Program 2, City Planning, will reduce the time normally needed to complete the requirements for the graduate degrees. Other suitable undergraduate Courses are Civil Engineering (Course I), Economics (Course XIV), Political Science (Course XVII), Management (Course XV), Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B). 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 (COURSE XI)

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

law, and public administration all offer suitable preparation. Applicants from other fields are also accepted.

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 Science. Four one-semester college subjects 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.

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 field is also desirable.

Deficiencies in any of the above areas may be removed by taking comparable subjects at M.I.T.

The Graduate Degrees

MASTER IN CITY PLANNING

The typical program leading to the degree of Master in City Planning requires two to three years of study at M.I.T., depending both upon prior preparation and upon the specialization chosen.

No program of required subjects is prescribed. Each student, whether through previous experience, formal subjects, or independent study, is expected to acquire an understanding of a core of fundamental knowledge and skills, and to develop competence in some more specialized area. He sets his own program in collaboration with a faculty advisor in the light of his particular background and interests. His area may be in one of the fields described below, under Opportunities for Specialization, or may be in some other area related to urban or regional development in which this department, or other M.I.T. departments, can offer advanced work. The core knowledge expected of all graduate students includes the following elements:

1. A general understanding of contemporary urban society and its major components: social, economic, spatial, and political.
2. Skill in the techniques for analyzing urban and regional communities: their social and economic characteristics, spatial patterns, political structure, behavioral impact, and processes of change.
3. Skill in the synthesis of development policy, including the statement of the problem, the formulation of objectives, the generation and evaluation of alternative plans and policies, their implementation, and the monitoring and adjustment of action.

Subjects offered in this Department and listed under Descriptions of Subjects will usually provide the base for each student's specialization, as well as a resource for the required core of fundamental knowledge and skills. Students are also encouraged to take relevant subjects in other M.I.T. departments, and may cross-register at Harvard University for specialized subjects not available at M.I.T.

Students are usually required to have the equivalent of at least one summer's practical experience in urban development work or in advanced research. An original thesis is required, occupying at least one term and often longer.

DOCTOR OF PHILOSOPHY

Advanced students seeking 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. The general requirements for the Ph.D. degree are specified in Section 3 of this Catalogue.

Doctoral candidates must prepare for three general examinations, one covering basic planning fundamentals, the second on planning theory, and the third on the area of concentration chosen by each candidate. This area may be in any field related to city and regional planning in which this Department or other M.I.T. departments offer strong support.

Upon successful completion of examinations, the student is required to prepare a written doctoral thesis evidencing the capacity to do independent research.

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.

Doctoral study in city and regional planning may be associated with the research program of the Joint Center for Urban Studies of M.I.T. and Harvard University.

Architecture

DEPARTMENT OF CITY AND REGIONAL PLANNING

OPPORTUNITIES FOR SPECIALIZATION

Several concentrations of study in workshops and seminars are available, to both Master's and doctoral candidates. Complementing the Department's original focus on urban and metropolitan design and implementation, with stress on land use and housing, newer concentrations include:

Planning problems of the developing countries of the world: Both regional and urban development planning are covered, extending from analysis of urban housing or economic growth problems to strategy of policy formulation and programming.

City Design: The Department offers special training in the field of city design — the spatial organization of activities and the shaping of the physical environment at city scale, with special reference to its esthetic qualities, its effects on psychological processes and immediate behavior. Our training and research in design at the city, rather than the project, scale is for the present a unique program. It seeks to develop a basic competence in city planning and in the method of design at that scale as well as a more special competence in understanding the visual consequences of city form.

Transportation planning: This work deals with the relationships between the patterns and channels of movement and the spatial arrangement of human activities; it builds on the increasing attention to urban and interurban transportation throughout M.I.T.'s other schools.

Social and Political Aspects of Urban Planning: A special concentration is available focusing on the social impact of urban development programs; race relations, housing, and poverty; political participation in urban affairs; and urban policy in the context of intergovernmental relations. This specialization is possible within the Master's and doctor's programs, and includes course work in the M.I.T. Department of Political Science.

Economics and Planning: Students may pursue a doctoral program combining study in this Department with study in the Department of Economics. Achievement of a high level of scholarly competence in both fields is required. Planning students may also devise Master's and doctoral programs consistent with their prior preparation with varying degrees of concentration in urban economics and other relevant coursework offered in both departments.

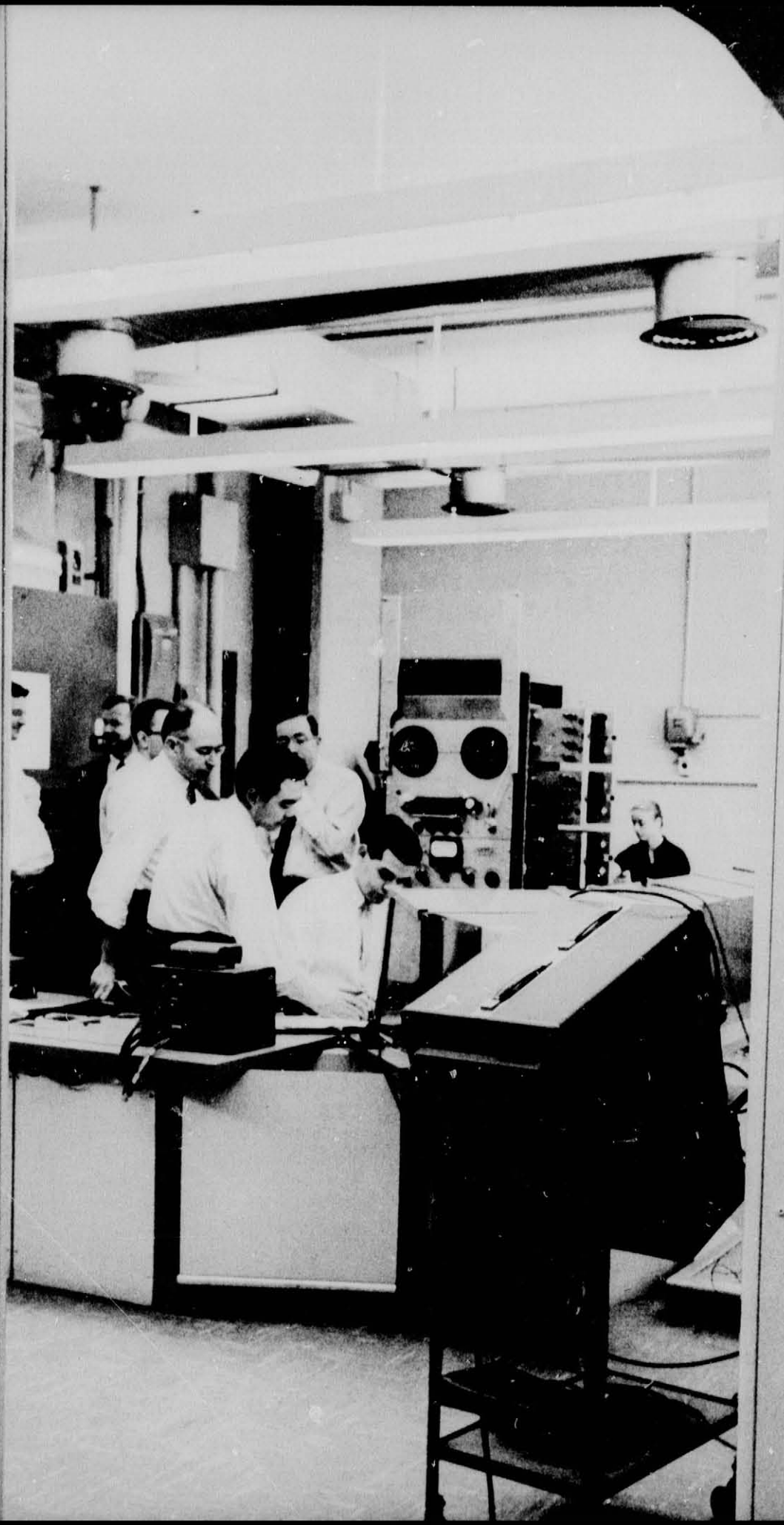
Quantitative methods in urban and regional studies and planning: New problems and programs in urban affairs require the development of new quantitative approaches. Students entering with some mathematics background may be particularly interested in subjects and seminars in the design and use of information systems, the simulation of complex models (including demographic and metropolitan applications), probabilistic systems, decision theory and optimal programming. The special computer facilities in the Institute and the Department provide a rich context for this work.

SPECIAL PROGRAM FOR URBAN AND REGIONAL STUDIES OF DEVELOPING AREAS (SPURS)

This program provides an opportunity for a small number of unusually qualified persons to carry out a program of study and research for one academic year outside the regular degree requirements. The work of this group of Fellows will be focused on the problems of urban and regional change within the broad context of national development. The main aim is to make it possible for some of the persons who will be shaping policy in the developing nations in the years to come to enhance their capacity to cope with these problems.

Participants in the program will be mature individuals who are now occupying or are likely to occupy significant positions in private or public organizations. They may be drawn from such varied fields as architecture, sociology or economics, from government or business, from any field in which there is a concern with problems of development. Preference will be given to persons from the developing countries, but some participants may come from Western Europe or the United States. The principal criteria for admission are the exceptional ability, experience and position of the individual. All applicants must have a thorough command of English.

The program is flexible. Fellows will be encouraged to tailor their work to their own individual requirements. They would generally be permitted to select subjects offered at M.I.T. normally available to graduate students, subject to the approval of the instructor. Fellows may also pursue their own research or, when feasible, participate in ongoing programs. All Fellows will attend a program's special seminar on policy problems of urban and regional development.



SCHOOL OF ENGINEERING 5.

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 are at last achieving 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. In the future, the engineer will be called upon to participate with increasing frequency and in greater depth in programs that cut across a wide spectrum of disciplines and involve an increasing number of social and economic factors. The opportunities for the engineer to provide leadership in these areas are vast. 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 34,000 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 advisors to government on many important issues.

The various curricula within the School of Engineering are sufficiently general to assure that no student is confined to a narrow specialization. In fact, specialized knowledge is now of such quantity and its application is so sophisticated that it cannot be mastered in four, five, or even six years. Further-

more, 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 encompasses study of the basic sciences, mathematics, and humanities. In the sophomore year, the student normally continues these studies with subjects leading to the fulfillment of the Science Distribution, Laboratory, and Humanities requirements. While some technical and professional subjects that lead to a major field may begin in the sophomore year, the majority of these subjects are taken in the later years.

Mature professional education may begin during the senior year but finds its full expression only 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-fourth 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 to fill the elective time 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 each department 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

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

ROBERT HUGH SCOTT
Assistant Dean, Administration

ROBERT PAUL GREENE, S.B.
Administrative Assistant

ENGINEERING COUNCIL

RAYMOND LEWIS BISPLINGHOFF, DR.SCI. TECHN., SC.D., ENG.D.
Head, Department of Aeronautics and Astronautics

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

CHARLES LESLIE MILLER, S.M.
Head, Department of Civil Engineering

LOUIS DIJOUR SMULLIN, S.M.
Head, Department of Electrical Engineering

ASCHER HERMAN SHAPIRO, SC.D.
Head, Department of Mechanical Engineering

THOMAS BURNESS KING, PH.D.
Head, Department of Metallurgy and Materials Science

ALFRED ADOLF HEINRICH KEIL, DR.RER.NAT.
Head, Department of Naval Architecture and Marine Engineering

MANSON BENEDICT, PH.D. (*Absent*)
Head, Department of Nuclear Engineering

ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.
Acting Head, Department of Nuclear Engineering

PIERRE LEONCE THIBAUT BRIAN, SC.D.
School Representative on the Faculty Committee on Educational Policy

HAROLD SOMERS MICKLEY, SC.D.
Director, Center for Advanced Engineering Study

SCHOOL PROFESSORS

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

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

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 subjects 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. Examples of Course schedules are issued each term by the Registrar with the Class Schedules. R.O.T.C. subjects may be used according to the specifications in Section 2.

GENERAL INSTITUTE REQUIREMENTS

					Total units
Specific Science Subjects					
5.01	CHEMISTRY	5	0	7	
8.01	PHYSICS I	5	0	7	
8.02	PHYSICS II	5	0	7	
18.01	CALCULUS	4	0	8	
18.02	CALCULUS	4	0	8	
					60
Humanities and Social Science Subjects (*See pages 50–55*)					**68**
					128

Science Distribution Requirement
At least 36 units in three fields (*see the list on pages 48–49*)

Laboratory Requirement
At least 12 units (*see page 49*)

Engineering

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

Department of Aeronautics and Astronautics

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Professor of Aeronautics and Astronautics; Head of the Department

ROBERT LOUIS HALFMAN, S.M.
Professor of Aeronautics and Astronautics; Deputy Head of the Department

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

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

MILTON URE CLAUSER, PH.D.
Professor of Aeronautics and Astronautics; Director of Lincoln Laboratory

EUGENE EDZARDS COVERT, SC.D.
Professor of Aeronautics and Astronautics

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

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

JOHN VINCENT HARRINGTON, SC.D.
Professor of Aeronautics and Astronautics; Director of the Center for Space Research

HEINRICH HERTEL
Professor of Aeronautics and Astronautics (Visiting)

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

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

MIKHAIL NAUMOVICH KOGAN, D.MATH.SC.
Professor of Aeronautics and Astronautics (Visiting)

OTTO CARL KOPPEN, S.B.
Professor of Flight Vehicle Engineering, Emeritus; Senior Lecturer

MARTEN TEODOR LANDAHL, TEKN.D. *(Absent)*
Professor of Aeronautics and Astronautics

YAO TZU LI, SC.D. *(Absent)*
Professor of Aeronautics and Astronautics

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

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

JAMES ELLIOT MCCUNE, PH.D.
Professor of Aeronautics and Astronautics

WALTER MCKAY, S.M.
Professor of Aeronautics and Astronautics

RENE HARCOURT MILLER, M.A.
H. N. Slater Professor of Flight Transportation

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

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

ROBERT CHANNING SEAMANS, JR., SC.D.
Jerome Clarke Hunsaker Professor of Aeronautics and Astronautics (Visiting)

ERNST AUGUST STEINHOFF, PH.D.
Professor of Aeronautics and Astronautics (Visiting)

EDWARD STORY TAYLOR, S.B.
Professor of Flight Propulsion, Emeritus; Senior Lecturer

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

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

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

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

SECOR DELAHAY BROWNE, A.B.
Associate Professor of Flight Transportation

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

MICHAEL JUDD, PH.D.
Associate Professor of Aeronautics and Astronautics (Visiting)

ELMER EUGENE LARRABEE, S.M. *(Absent)*
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WILLIAM STEPHEN LEWELLEN, PH.D.
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ROBERT KARL MUELLER, SC.D.
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JAMES EMERSON POTTER, PH.D.
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ROBERT WARREN SIMPSON, SC.D.
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HAROLD YEHUDA WACHMAN, PH.D.
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EMMETT ATLEE WITMER, SC.D.
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LAURENCE RETMAN YOUNG, SC.D.
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SHAOUL EZEKIEL, SC.D.
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NORMAN DOUGLAS HAM, AER.E.
Assistant Professor of Aeronautics and Astronautics

WALTER MARK HOLLISTER, SC.D.
Assistant Professor of Aeronautics and Astronautics

JACOB LEON MEIRY, SC.D.
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JAMES PATRICK MORAN, S.M.
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DAVID ANTHONY OLIVER, PH.D.
Assistant Professor of Aeronautics and Astronautics
ALBERT SOLBES, PH.D.
Assistant Professor of Aeronautics and Astronautics
DAVID BRUCE STICKLER, PH.D.
Assistant Professor of Aeronautics and Astronautics
CHRISTOPHER KWONG WAH TAM, PH.D.
Assistant Professor of Aeronautics and Astronautics; Postdoctoral Fellow in Engineering
PIN TONG, PH.D.
Assistant Professor of Aeronautics and Astronautics
SHEILA EVANS WIDNALL, SC.D.
Assistant Professor of Aeronautics and Astronautics

Administrative Officer

JOHN RONALD MARTUCCELLI, S.M.

Lecturers

RAMON LUIS ALONSO, PH.D.
MICHAEL SAMPSON BARAM, B.S., LL.B.
RICHARD HORACE BATTIN, PH.D.
HOWARD DEMUTH, PH.D.
ELMER JACOB FREY, PH.D.
JOHN HOVORKA, SC.D.
ANDREW JAMES LINCOLN, PH.D.
ROBERT GOTTLIEB STERN, PH.D.

Technical Instructors

JOHN BARLEY
ALLAN RALPH SHAW

Research Associates

CHARLES WALDO HALDEMAN, SC.D.
JOEL BRADFORD SEARCY, SC.D.

Professors Emeriti

FRANK KINGSLEY BENTLEY
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CHARLES STARK DRAPER, SC.D.
Institute Professor Emeritus; Professor of Aeronautics and Astronautics, Emeritus; Director of the Instrumentation Laboratory
JEROME CLARKE HUNSAKER, SC.D., ENG.D.
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Professor of Flight Vehicle Engineering, Emeritus; Senior Lecturer
JOHN RAYMOND MARKHAM
Professor of Aeronautical Engineering, Emeritus
SHATSWELL OBER, S.B.
Professor of Aeronautical Engineering, Emeritus
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Professor of Flight Propulsion, Emeritus; Senior Lecturer

AERONAUTICS AND ASTRONAUTICS

The engineer is sometimes described as a builder of bridges between science on the one hand and the needs of society on the other. The engineer practicing in the fields of aeronautics and astronautics bridges science with the specific social needs of transportation, national defense and the exploration of space. Aeronautics embraces the atmospheric flight of vehicles ranging from hovercraft and helicopters to the supersonic transport. Astronautics involves the flight of such vehicles as long-range ballistic missiles, satellites, and interplanetary spacecraft beyond the atmosphere in the vast airless regions of space. The objective of the education offered by the Department of Aeronautics and Astronautics is to prepare its graduates for leadership in the processes of research, development and operation as they relate to aeronautical and astronautical vehicles. To serve these objectives the Department curriculum, in addition to the Institute core offerings in humanities, science and mathematics, embraces the engineering sciences and technologies which are regarded as fundamental to contemporary aeronautics and astronautics. There is at the same time a strong emphasis on systems subjects, available as electives, which are superimposed upon the several disciplinary subjects and act as a means for giving the student an awareness of the relations among them and a feeling for the interconnected whole.

The interests and fields of specialty of the faculty of the Department range from the aeronautical and space sciences and technologies on the one hand to systems engineering on the other. This variety in background and interest makes it possible for the Department to offer a balanced education in aeronautics and astronautics with flexibility to meet student desires and to encourage maximum development of individual abilities. Engineering science electives are offered to those interested primarily in research, while professional engineering subjects are available to those attracted to engineering development and operations. Throughout the Department's offerings, the view is taken that it is less important for the student to learn specialized knowledge in detail than it is to acquire the attitudes of applying science to achieve engineering objectives; to learn how to explore new technical ideas, express and test them and examine their implications; and to develop a feeling for the innovations, compromises, judgments

and attention to detail required for technological advancement. Every subject taught by the Department is regarded as an instrument to instill these attitudes in its students.

In order to deal effectively with the range of subjects underlying the processes of research, development and operations, the Department faculty is presently divided into five major divisions of instruction. Each division includes faculty members and subject offerings which are fundamental to both aeronautics and astronautics. The five divisions are the following: mechanics and physics of fluids; materials, structures and aeroelasticity; propulsion and space power; aeronautical and astronautical systems; instrumentation, control and guidance. Many faculty members work with more than one division, thereby promoting a broader understanding within the faculty of the conditions associated with the research, development and operation of flight vehicle systems. Because of the exceptionally stringent character of these conditions, the small design margins that separate success from failure make the problems of flight vehicle engineering among man's most difficult and challenging.

Progress in aeronautics and astronautics continues to be so rapid that effective education must deal not only with the circumstances of today but also those to be expected in the future. Faculty service with government and industry advisory committees and consulting on significant aerospace problems help fulfill the need for coupling education with current practice. Another means for insuring that faculty members continue to be well informed and retain leadership in their professional areas is active personal participation in research. An important characteristic of the Department is that, on the basis of his own free choice, each faculty member may be associated with research work in either academic facilities or laboratories assisted by outside sponsorship. Experience and information gained from such research is generally incorporated first in graduate subjects and is then applied to the updating of all subjects offered by the Department. The laboratories also make it possible for undergraduates at all levels, including freshmen, for graduates, and for postgraduates to work with faculty members on a wide variety of advanced projects. Students frequently assist with laboratory work, carry out special projects, and use laboratory facilities; they have the advantage of advice from the laboratory staff on undergraduate and graduate theses. The laboratories also have funds to pay for service not associated with academic credit, so that students often can earn money toward academic expenses while gaining valuable professional experience.

The Department is organized for research into two divisions, each with several sections. The Aerospace Research Division includes the Fluid Dynamics Research Laboratory, the Aerophysics Research Laboratory, the Aeroelastic and Structures Research Laboratory, the Wright Brothers Wind Tunnel Facility, the Space Propulsion Laboratory, the Experimental Astronomy Laboratory, the Man-Vehicle Control Laboratory, the Gas Turbine Laboratory and various facilities used for individual research by faculty members. The Instrumentation Division includes the guidance systems section, the guidance component section, and the guidance test facilities sections.

The Aerospace Research Division has equipment for research in all regions of flight, from hovering to interplanetary operations. Gas dynamic research is carried out in the hypersonic wind tunnel (Mach number 7.5) and in the supersonic wind tunnel of the Aerophysics Research Laboratory. Fluid mechanics research occupies a low-speed, low-turbulence wind tunnel. Two larger low-speed wind tunnels are used for airplane and helicopter research. Structural dynamics research, including blast and high-velocity impact effects, is carried on in the Aeroelastic and Structures Research Laboratory. Facilities for ion propulsion studies are available in the Space Propulsion Laboratory, while the Gas Turbine Laboratory, manned jointly with the Department of Mechanical Engineering, conducts research on the aerodynamics of turbines, compressors, combustion, and mixing jets. The Experimental Astronomy Laboratory is engaged in research on interplanetary navigation systems and in research and flight-testing of systems for celestial observations from stations in the upper atmosphere. Simulator equipment is used for studying human reactions in the Man-Vehicle Control Laboratory.

The Instrumentation Division pioneers in the development of control and guidance equipment for aircraft, missiles, and space vehicles. Inertial guidance receives special attention, and the Laboratory is equipped with advanced facilities for research on all phases of control and guidance. Projects dealing with systems for helicopters, airplanes, submarines, missiles, satellites, and manned lunar craft are currently in

progress and offer many kinds of student participation.

In addition to the research facilities described, a Projects Laboratory is maintained for the purpose of allowing students to carry out experiments which they themselves conceive and design. Students who have acquired reasonable levels of skill in the Projects Laboratory usually move into other laboratories of the Department.

THE UNDERGRADUATE CURRICULUM

Aeronautics and Astronautics (Course XVI)

Undergraduate study in the Department leads to the degree of Bachelor of Science in Aeronautics and Astronautics at the end of four years. The curriculum provides flexibility to meet the needs of careers in aerospace activity ranging from scientific research to responsible engineering direction of large enterprises. Each student elects an individual program tailored to his interests, built on firm grounding in science and on a broad base in the engineering sciences, from a wide selection of available subjects. With the advice of his Faculty Counselor, he plans an undergraduate program which is reviewed each term and which may be changed at any time. The curriculum requirements for the Bachelor of Science degree are as follows:

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)				
	Specific science and humanities and social science subjects			**128**
	The subjects 8.03T, 16.20, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.			
	The subject 16.62, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.			
DEPARTMENTAL PROGRAM				
	Required Subjects			
16.001	THERMODYNAMICS AND STATISTICAL MECHANICS	4	2	6
8.03T	PHYSICS III	5	0	7
16.20	SOLID MECHANICS I	4	2	6
18.034	DIFFERENTIAL EQUATIONS	3	0	9
3.141	SCIENCE OF MATERIALS	4	3	5
6.14	ELECTRONIC NETWORKS AND DEVICES	4	2	6
16.01	DYNAMICS	4	2	6
16.62	EXPERIMENTAL PROJECT	2	6	4
				96
	Restricted Electives			
16.02	AERODYNAMICS *or*	4	2	6
16.03	GASDYNAMICS			
	At least three subjects chosen from the following:			
16.031	TOPICS IN FLUID MECHANICS *or*	3	0	6
16.11	AERODYNAMICS OF FLIGHT VEHICLES			
16.201	SOLID MECHANICS II	4	0	6
16.30	PRINCIPLES OF AUTOMATIC CONTROL	3	0	9
16.40	PRINCIPLES OF FLIGHT GUIDANCE	3	0	9
16.53	ROCKET PROPULSION *or*	3	0	6
16.54	AIRCRAFT ENGINES			
16.71	FLIGHT VEHICLE ENGINEERING *or*	2	3	7
16.73	SPACE SYSTEMS ENGINEERING	4	0	8
				40 to **48**
	Unrestricted Electives[1]			**96** to **88**
Total units required for the S.B. degree				**360**

[1] Schedules of students in Course XVI may always be arranged to leave available 24 units of unrestricted elective in the second year.

During the first two years, subjects elected by the student will be mainly in the areas of science and engineering science. If he wishes to specialize as fully as possible in his education in aeronautics and astronautics, he will choose subjects recommended by the Department, thereby gaining flexibility and elective freedom in his upper years. These subjects are in varied fields, in keeping with the wide range of the Department's interests, so that this course of action is consistent with a desire for program diversity and breadth.

Usually a student begins to follow the program in aeronautics and astronautics in the fall of his second year. During that year, he is advised to take the first four subjects listed above, namely 8.03T, 18.034, 16.001 and 16.20. He may also, with profit, elect 3.141, if he has not already done so as a freshman. Other desirable choices would include mathematics beyond 18.034, physics beyond 8.03T, fields in continuous media, 16.09, or, from the above list, 16.01 or 6.14.

A student who elects Course XVI at the end of his second year can arrange an acceptable program by using some of the elective freedom available in the upper years to satisfy the departmental subject requirements. However, such a program will be correspondingly limited in depth.

During the first two years and apart from science and engineering science subjects, many students will wish to obtain a broad view of the aerospace field or a deeper insight into one of its aspects under the tutelage of an experienced engineer or scientist. Undergraduate electives and seminars meet this need.

During the third and fourth years programs may be drawn from a wide range of subjects,

depending on a student's interests. As a base, he may well use some of his elective freedom to take more than three of the six restricted electives listed above. He will still have opportunity to choose continuing subjects in the Department's varied fields of interest. Any student may elect to do a Bachelor's thesis in his fourth year.

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

The cooperative program for Aeronautics and Astronautics undergraduates provides the opportunity to spend about seven months in an aerospace organization before the senior year. This length of industrial practice enables the student to advance to more interesting and professionally rewarding experience than can be gained in summer employment. The program permits completion of requirements for the Bachelor's degree in four years.

Students in the program become regular employees during their period of employment and are subject to the regulations of the company. Cooperating companies in the aerospace industry pay students at prevailing rates during their period of employment. Students pay their own expenses while away from the Institute.

A student interested in the program should apply to the professor in charge for particulars and an interview and also should, with his Faculty Counselor, arrange a schedule which permits his absence from Cambridge during the second term of the third year. This should be done before January of the sophomore year since subject choices in the second term of the second year may be affected.

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 in place of 8 units of elective:

16.85	INDUSTRIAL PRACTICE	0	8	0

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:

Aerodynamics and gasdynamics
Aeroelasticity
Aeronautical and astronautical engineering
Automatic control
Flight guidance
Flight transportation
Fluid mechanics
Instrumentation
Physics of fluids
Plasma physics and space sciences
Propulsion
Space mechanics
Structures
Vehicle design

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.

Entrance Requirements for Graduate Study

In addition to the general requirements for admission to the Graduate School, all applicants must have a strong undergraduate background in fundamentals of mechanics, thermodynamics, and electrical science. 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

The general requirements for the Master's degree are given in Section 3. To complete the requirements of at least 66 subject units, of which 42 units must be in "A" subjects, and an acceptable thesis generally takes one academic year. Two terms of advanced mathematics beyond DIFFERENTIAL EQUATIONS (18.034) or its equivalent must be included.

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

ENGINEER IN AERONAUTICS AND ASTRONAUTICS

The general requirements for the Engineer degree are given in Section 3. The minimum program of 162 subject units and an acceptable thesis usually takes at least two years for comple-

tion. 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. The Department may accept a Master's thesis of superior quality for the Engineer's degree.

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)

The general requirements for the doctor's degree are given in Section 3. 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 Minor program is required. 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.

SPECIALIZATION IN THE FIELD OF INSTRUMENTATION

For the doctor's degree, the student is required to complete an approved program and a thesis in one of the interrelated fields of instrumentation which include automatic control; navigation and guidance of vehicles; optimum control principles and their application to various types of plants; information systems, and system components. This program involves study in and participation by the Departments of Aeronautics and Astronautics, Electrical Engineering, Mechanical Engineering, Mathematics, and Physics. It 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.

SPECIALIZATION IN THE FIELD OF 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 materials 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 or Doctor of Philosophy. 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 or Doctor of Philosophy 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

There is no language requirement for candidates for the Master of Science or Engineer degrees. A candidate for a doctoral degree is normally required to complete the Institute language requirement before his third year in residence. The choice of plan and languages must have prior approval of his Graduate Registration Officer.

Financial Assistance for Graduate Study

The Department offers several fellowships for full-time study in aeronautics and astronautics.

The fellowships, which allow students to pursue full-time programs of study, are described in Appendix A of this Catalogue.

The assistantship program provides a unique opportunity to progress toward a graduate degree through combined registration for academic subjects and research leading to the thesis. The research assistant works with a faculty supervisor on a specific research assignment. The experience gained in organizing work, in learning and applying new experimental techniques and analytical tools, and in technical writing, is invaluable in any career in engineer-

ing. In most cases, a student can be placed in the technical area in which he desires to concentrate his study and to carry on his thesis research.

The Department also offers a limited number of teaching assistantships.

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

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

PIERRE LEONCE THIBAUT BRIAN, SC.D.
Professor of Chemical Engineering

THOMAS BRADFORD DREW, S.M.
Professor of Chemical Engineering, Emeritus; Senior Lecturer

HOYT CLARKE HOTTEL, A.B., S.M.
Professor of Chemical Engineering, Emeritus; Senior Lecturer

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

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

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

HAROLD SOMERS MICKLEY, SC.D.
Ford Professor of Chemical Engineering; Director of the Center for Advanced Engineering Study

GEOFFREY D. PARFITT, PH.D.
Carbon P. Dubbs Professor of Chemical Engineering (Visiting)

ROBERT CLARK REID, SC.D.
Professor of Chemical Engineering

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

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

JOHNSON EDWARD VIVIAN, SC.D. (*Absent*)
Professor of Chemical Engineering

GLENN CARBER WILLIAMS, SC.D. (*Absent*)
Professor of Chemical Engineering

LAWRENCE BOYD EVANS, PH.D.
Associate Professor of Chemical Engineering

ALLAN SACHS HOFFMAN, SC.D.
Associate Professor of Chemical Engineering

ADEL FARES SAROFIM, SC.D.
Associate Professor of Chemical Engineering

KENNETH ALAN SMITH, SC.D.
Associate Professor of Chemical Engineering

SAMUEL WRIGHT BODMAN, III, SC.D.
Assistant Professor of Chemical Engineering

WILLIAM HOWARD DALZELL, SC.D. (*Absent*)
Assistant Professor of Chemical Engineering

MAX CURTIS DEIBERT, SC.D.
Assistant Professor of Chemical Engineering

JACK BENNEY HOWARD, PH.D.
Assistant Professor of Chemical Engineering

MICHAEL MODELL, SC.D.
Assistant Professor of Chemical Engineering

JAMES JEFFREY NOBLE, PH.D.
Assistant Professor of Chemical Engineering

K. SOMMASUNDRA RAO, D.SC.
Assistant Professor of Chemical Engineering (Visiting)

CHARLES WILLIAM SELVIDGE, SC.D.
Assistant Professor of Chemical Engineering; Director of the Bound Brook Station, School of Chemical Engineering Practice

PREETINDER SINGH VIRK, PH.D.
Assistant Professor of Chemical Engineering

Administrative Officer

MARGARET SCHULER BARRETT

Technical Instructors

HAROLD HAVNER CARTER

REED CAMPBELL FULTON

Senior Research Associates

W. GERALD AUSTEN, M.D.

EDWIN W. SALZMAN, M.D.

STATIONS OF THE SCHOOL OF CHEMICAL ENGINEERING PRACTICE

Directors

SAMUEL McCLAIN FLEMING, S.M., *Oak Ridge (Also Instructor)*

CHARLES WILLIAM SELVIDGE, SC.D., *Bound Brook*

Assistant Directors and Instructors

JUAN MIGUEL MEYER, S.B. *Bound Brook*

PAUL JOSEPH WOOD, S.M. *Oak Ridge*

Professors Emeriti

THOMAS BRADFORD DREW, S.M.
Professor of Chemical Engineering, Emeritus; Senior Lecturer

HOYT CLARKE HOTTEL, A.B., S.M.
Professor of Chemical Engineering, Emeritus; Senior Lecturer

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

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

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

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

Engineering

DEPARTMENT OF CHEMICAL ENGINEERING

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 areas such 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 Department of Chemical Engineering 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). The 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 School of Chemical Engineering Practice involves one term of work under the direction of Institute faculty at the Practice School Stations. There each student has a unique opportunity to develop the ability to apply basic professional principles to the solution of practical problems in industry. Study at the field stations is generally included in a program for an advanced degree but is also available for undergraduates in the second term of the senior year.

THE UNDERGRADUATE CURRICULA

The undergraduate subjects 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.

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.

The curriculum is designed to give undergraduates a sound basis for further developing their aptitudes and interests through industrial work, independent study, or graduate work.

In order to permit different undergraduate programs, a wide latitude of free choice of subjects within the chemical and chemical engineering areas is provided. Consequently, each student should plan, with the aid of his Faculty Counselor, a program which fits his interests and capabilities. It is especially important that he recognize early the extent of his interest in 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 99*)					
	Specific science and humanities and social science subjects				**128**
	The subjects 5.60, 10.12, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement (see page 49)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
5.41	ORGANIC CHEMISTRY I	4	0	8	
5.60	CHEMICAL THERMODYNAMICS	4	0	8	
8.03T	PHYSICS III	5	0	7	
10.12	STAGED CASCADES IN CHEMICAL PROCESSING	3	3	6	
10.15	[1]THESIS REPORTS	0	4	0	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	THESIS	12			
					76
	Restricted Electives				
	Chemistry (in addition to the above required subjects)			at least	**36**
	Chemical engineering (in addition to the above required subjects)			at least	**56**
	Unrestricted Electives[2]			up to	**52**
	Laboratory work (within the above categories of electives, at least 18 units in addition to the General Institute Laboratory Requirement, 10.12, and THESIS)				
Total units required for the S.B. degree					**360**

[1] 10.15 is a "time-arranged" subject.

[2] Schedules of students in Course X may always be arranged to leave available 12 units of unrestricted elective in the second year.

Electives in chemistry are normally selected from the following: a second term of organic chemistry (5.42); further terms of physical chemistry (5.62, 5.63); analytical chemistry (5.14); a term of inorganic chemistry (5.03); and relevant laboratory subjects. Electives in chemical engineering normally include most of the following: a term of thermodynamics (10.13T); engineering operations (10.301 and 10.302; or 10.301, 10.311, and 10.312); structure and properties of non-metallic substances (10.21); industrial chemistry (10.18); chemical kinetics and reactor design (10.37); 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 Experimental Research Problem (10.91), 12 units of which satisfy the General Institute Laboratory Requirement. Students with a strong interest in a professional minor may satisfy this interest by use of the scheduled free elective time.

The student who decides early upon a major in chemical engineering is encouraged to start his professional subjects in the second year with chemical engineering (10.12 and 10.13T) and physical chemistry (5.60 and 5.62), and to take additional mathematics and physics. He will then be in an excellent position for professional work in some depth in the third and fourth years.

Some students may wish to defer choice of major field until the end of two years; or they may decide upon chemical engineering early but still wish, because of strong secondary interest in other engineering or scientific areas, to exercise maximum freedom in the first two years. They will have 12 units of elective time in the first year and, if their second year includes two subjects in humanities and a third term each of physics and mathematics, 48 units will remain to be chosen. If one of the Science Distribution Subjects chosen is in the field of fluid mechanics, thermodynamics or chemistry (examples: 2.403, 3.00, 5.41, 5.60), a student can generally complete the requirements for a degree in chemical engineering in two more years. This leaves 36 hours to his own choosing in the second year; but he will have sacrificed some of his elective freedom of the third and fourth years. He is advised to discuss his proposed program with a Course x Faculty Counselor as soon as he becomes interested in a degree in chemical engineering.

MATERIALS SCIENCE AND ENGINEERING

A sound training in the fundamental physics and chemistry which underlie the useful macroscopic properties of materials, and their response to environment and manipulative processes, has in recent years become of great importance to the engineering community at large and to the chemical engineering profession in particular. The area of polymeric materials (plastics, elastomers, coatings, and adhesives) occupies an important place in the domain of chemical engineering, and the Department offers a strong teaching and research program in this field.

Recognizing that a growing number of the students who are motivated toward chemical engineering as a profession may wish to develop special competence in the fundamentals of materials science, the Department offers a program in Materials Science and Engineering.

This program involves a significant study in chemistry and chemical engineering and an integrated program of subjects in the materials area offered by the Departments of Physics, Chemistry, Metallurgy and Materials Science, and Mechanical, Civil, Nuclear, Electrical, and Chemical Engineering. Students interested in this field should arrange with a Faculty Counselor a program that best fits their objectives.

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.

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 Engi-

neer, Materials Engineer, Doctor of Science or Doctor of Philosophy. 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 eight fields: applied chemistry, biochemical engineering, biomedical engineering, catalysis and reactor engineering, engineering operations, fuel engineering, materials engineering and polymers and plastics. 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 CHEMICAL THERMODYNAMICS (5.60) and PHYSICAL CHEMISTRY (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. A Minor is required by the Department.

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)
MECHANICS OF FLUIDS (10.52)
CHEMICAL ENGINEERING DESIGN (10.53)
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; and in the physical chemistry of ion-exchange, adsorption, and chromatography. The subjects listed under Materials Science and Engineering (below) also include several on applied chemistry. 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)
CATALYSIS (10.602)
ADVANCED THERMODYNAMICS (10.62)
APPLIED CHEMICAL KINETICS (10.65)
CHEMICAL ENGINEERING IN MEDICINE (10.56)

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.

MATERIALS SCIENCE AND ENGINEERING

The Department maintains an active and diversified graduate research program in surface and colloid chemistry, polymer chemistry, and polymer physics and offers a coordinated instructional program in these areas. Students whose interests lie in the direction of surface phenomena or polymeric materials thus have a rare opportunity to develop specialized skills in these areas in an atmosphere where the focus of atten-

tion is on the applied, as well as the basic, scientific aspects. Specific subjects offered are:

PHYSICS AND CHEMISTRY OF SURFACES (10.61)
STRUCTURE AND PROPERTIES OF POLYMERS (10.64)
SURFACE SCIENCE AND ENGINEERING (10.66)
PHYSICAL CHEMISTRY OF POLYMERS (10.68)
POLYMERIZATION PROCESSES (10.69)

Graduate research activities in these fields include topics such as the rheology of polymer solutions and particulate dispersions, molecular transport phenomena in polymers, structure and properties of microcrystalline thermoplasts, permselective membranes, chemisorption on semiconductors, fluid transport in microporous solids, crystal growth kinetics, and wetting processes. Collaboration between Chemical Engineering and many other departments in the supervision of these research projects brings an interdisciplinary approach to the entire program.

For students with strong interest in materials and an adequate background in chemistry or chemical engineering, the Department offers special graduate curricula leading to the degrees of Materials Engineer and Doctor of Science or Doctor of Philosophy. These curricula are designed to provide a properly integrated background in the science and engineering of the major classes of materials (metals, ceramics, and polymers) and also to specialize in some depth in a selected area of the field. Specific graduate programs are suggested by, and subject to the approval of, an interdepartmental committee on materials engineering. Further details may be obtained by consulting the Department Graduate Registration Officer.

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, radiation, 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)
MECHANICS OF FLUIDS (10.52)
APPLIED CHEMICAL KINETICS (10.65)
PRINCIPLES OF COMBUSTION (10.70)
SEMINAR IN HIGH TEMPERATURE PHENOMENA (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 at the American Cyanamid Company plant in Bound Brook, New Jersey, and the Oak Ridge National Laboratory of the Atomic Energy Commission, in Oak Ridge, Tennessee. 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. 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 until the end of January, and then return to the Institute to complete the program for the Master's degree during the spring term. Practice School experience (10.82 and 10.83; or 10.86 and 10.87) may be substituted for the S.M. thesis in Course X. A similar Practice School field program starts in February and extends to early June.

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.

Engineering

DEPARTMENT OF CIVIL ENGINEERING

Department of Civil Engineering

CHARLES LESLIE MILLER, S.M.
Professor of Civil Engineering; Head of the Department; Director of the Urban Systems Laboratory

JOHN MELVIN BIGGS, S.M.
Professor of Civil Engineering

JOHN CLARKESON, SC.D.
Professor of Civil Engineering (Visiting)

JOHN FREDERICK COLLINS, PH.D., D.C.L.
Professor of Urban Affairs (Visiting)

PETER STURGES EAGLESON, SC.D.
Professor of Civil Engineering

ROBERT JOSEPH HANSEN, SC.D.
Professor of Civil Engineering

DONALD ROBERT FERGUSSON HARLEMAN, SC.D.
(Absent)
Professor of Civil Engineering

MYLE JOSEPH HOLLEY, JR., S.M.
Professor of Civil Engineering

ARTHUR THOMAS IPPEN, PH.D.
Ford Professor of Engineering

THOMAS WILLIAM LAMBE, SC.D.
Professor of Civil Engineering

FREDERICK JEROME McGARRY, A.B., S.M.
Professor of Civil Engineering

ROBERT VAN DUYNE WHITMAN, SC.D.
Professor of Civil Engineering

ALEXANDER JAMIESON BONE, S.M.
Associate Professor of Civil Engineering, Emeritus; Senior Lecturer

JEROME JOSEPH CONNOR, JR., SC.D.
Associate Professor of Civil Engineering

CARL ALLIN CORNELL, PH.D.
Associate Professor of Civil Engineering

ALAN MARTIN HERSHDORFER, PH.D.
Associate Professor of Civil Engineering

RONALD COLMAN HIRSCHFELD, PH.D.
Associate Professor of Civil Engineering

RUSSEL CAMERON JONES, PH.D.
Associate Professor of Civil Engineering

CHARLES CUSHING LADD, SC.D.
Associate Professor of Civil Engineering

WILLIAM ALBERT LITLE, SC.D.
Associate Professor of Civil Engineering

ROBERT DANIEL LOGCHER, SC.D.
Associate Professor of Civil Engineering

MARVIN LEE MANHEIM, PH.D.
Associate Professor of Civil Engineering

RONALD THEODORE McLAUGHLIN, PH.D.
Associate Professor of Civil Engineering

CHIANG CHUNG MEI, PH.D.
Associate Professor of Civil Engineering

EUGENE MIRABELLI, S.B.
Associate Professor of Civil Engineering, Emeritus; Senior Lecturer

FRED MOAVENZADEH, PH.D.
Associate Professor of Civil Engineering

PETER JAN PAHL, SC.D.
Associate Professor of Civil Engineering

FRANK EDWARD PERKINS, SC.D.
Associate Professor of Civil Engineering

KARL-HEINRICH SCHRADER
Associate Professor of Civil Engineering (Visiting)

JAY RODNEY WALTON, PH.D.
Associate Professor of Civil Engineering

LESLIE GLENN BROMWELL, SC.D.
Assistant Professor of Civil Engineering

JOHN THOMAS CHRISTIAN, PH.D.
Assistant Professor of Civil Engineering

RALPH HERBERT CROSS, III, PH.D.
Assistant Professor of Civil Engineering

RICHARD LAWRENCE DeNEUFVILLE, PH.D.
Assistant Professor of Civil Engineering

ZIAD MALEK ELIAS, SC.D.
Assistant Professor of Civil Engineering

LYNN WALTER GELHAR, PH.D.
Assistant Professor of Civil Engineering

MICHAEL BICK GODFREY, SC.D.
Assistant Professor of Civil Engineering

KENNETH FRANK REINSCHMIDT, PH.D.
Assistant Professor of Civil Engineering

JOSE MANUEL ROESSET VINUESA, SC.D.
Assistant Professor of Civil Engineering

DANIEL ROOS, PH.D.
Assistant Professor of Civil Engineering

JOHN CHRISTIAN SCHAAKE, JR., PH.D.
Assistant Professor of Civil Engineering

JOSEPH HOOVER STAFFORD, PH.D.
Assistant Professor of Civil Engineering

JOSEPH MARTIN SUSSMAN, PH.D.
Assistant Professor of Civil Engineering

ANWAR ERNEST ZAKI WISSA, SC.D.
Assistant Professor of Civil Engineering

Administrative Officer

TROND HANS KAALSTAD, S.M.

Senior Lecturers

HERBERT IRVING GROSS, B.S.

FRANK SIDNEY JONES, M.B.A.
Assistant Director of the Urban Systems Laboratory

EDWARD EMMET NEWMAN, S.M.

Lecturers

HENRY W. BRUCK, A.M.

MARY ELIZABETH SCHUMACKER, S.B.

Instructors

AGUSTIN JUAN FERRANTE, M.E.

ALDEN TAYLOR FOSTER, S.M.

RICHARD VERYL GOODMAN, S.M.

WILLIAM FRIDRIK JOHNSON, S.M.

STEVEN BARNETT LIPNER, S.M.

WAYNE MARTIN PECKNOLD, S.M.

RONALD ALAN WALTER, S.M.

Technical Instructors

DAVID DRISCOLL, S.B.

ALBERT JOSEPH O'NEILL, S.B.

Research Associates

HERBERT HEINRICH EINSTEIN, SC.D.

MARIO HORATIO GRADOWCZYK, SC.D.

ROBERT TORRENCE MARTIN, PH.D.

WILLIAM TERRANCE O'BRIEN, PH.D.

CETIN SOYDEMIR, M.E.

JOHN HOWARD SUHRBIER, S.M.

LYLE ANTHONY WOLFSKILL, PH.D.

Professors Emeriti

JOHN BRAZER BABCOCK, 3D, S.B.
Professor of Railway Engineering, Emeritus

ALEXANDER JAMIESON BONE, S.M.
Associate Professor of Civil Engineering, Emeritus; Senior Lecturer

EUGENE MIRABELLI, S.B.
Associate Professor of Civil Engineering, Emeritus; Senior Lecturer

WILLIAM EDWARD STANLEY, C.E.
Professor of Sanitary Engineering, Emeritus

CIVIL ENGINEERING

Creating the complex systems of constructed facilities needed for sound economic growth is the purpose of civil engineering. Billions of dollars are invested each year by industry and government throughout the world to meet the rapidly expanding demand for facilities for transportation, communication, energy, defense, water resources, urban development, housing, manufacturing, and distribution; civil engineering is a principal instrument for focusing man's scientific and technological skills on this task. The goal is the effective control of our environment. Many specialists including teams of scientists, engineers, architects, and managers, contribute to these ventures, but the successful civil engineer must be responsible for bringing together many skills in achieving the most efficient solution. Reflecting this challenge, the program of the Department of Civil Engineering is based upon three broad and interrelated areas — the applied earth sciences, structures and materials, and civil engineering systems — each of which will be briefly described.

Where the earth scientist is primarily concerned with investigations of the earth, the oceans, and the atmosphere on a global scale, the civil engineer concentrates upon the near-surface aspects of the earth. The civil engineer seeks a basic understanding of the physics and chemistry of soils, liquids, and gases, and how their quality is modified by man's activities.

Many facility systems are primarily composed of structures; these often are large and extensive, requiring materials which perform for extended time periods under complex loads while exposed to the natural actions from the environment. Thus a fundamental understanding of the physics, chemistry, properties, structure, and behavior of materials is basic to civil engineering; new types of materials and structures, coupled with modern analytical and design tools such as computers and models, constitute another dimension in the profession.

The interaction of the many elements essential to the planning, design, construction, operation, and management of civil engineering projects is of controlling significance; these operations may now be formulated in terms of systems which can be engineered for optimum functional modes. Modern developments in mathematical techniques, systems analysis, simulation, operations research, and computer methods make the synthesis of civil engineering systems a challenging new area for study and research.

Engineering

DEPARTMENT OF CIVIL ENGINEERING

The research program of the Department is both substantial and comprehensive, supported by extensive experimental facilities; access to the facilities of other groups within the Institute further extends this capability. In all such activities, both undergraduate and graduate students participate to the fullest degree, working together with faculty who are widely known for their research accomplishments.

EDUCATIONAL FACILITIES

Areas of principal teaching and research interest within the Department are described below in terms of the departmental laboratories.

The *Hydrodynamics Laboratory* is a major unit for experimental research in fluid mechanics containing over 25,000 square feet devoted to laboratories, shops, and offices. Research equipment includes several flumes for free surface flow, a sedimentation flume, a large wave tank, a towing tank, a water tunnel, a channel for turbulent diffusion studies, a cavitation tunnel, closed test conduits, calibration facilities, and model basins. Instrumentation and data reduction equipment also are available to record and analyze both steady and transient flow phenomena.

The *Soil Research Laboratory* carries out research on the engineering behavior and fundamental physicochemical properties of soils. In addition to conventional soil testing equipment, the Laboratory has extensive facilities for research in soil dynamics, soil stabilization, soil-structure interaction, and soil technology. Several constant-temperature rooms house varied triaxial shear apparatus with electronic recording elements for investigating the influence of stress systems on the compression and strength behavior of clays, the dynamic properties of soil, and changes in engineering properties with environment. Deformation characteristics of buried structures, the settlement of structures, the stability of retaining walls, and seepage through earth dams are being studied with model tests. A program of field measurements evaluates the performance of building foundations on the M.I.T. campus.

The *Structures Research Laboratory* is devoted to research on the behavior of structural elements and materials under both static and dynamic loads to help develop theoretical solutions, design parameters, and design procedures for structural systems. A new effort, the Laboratory for Structural Models, shared jointly with the School of Architecture, is equipped to fabricate and test complex scale models such as shells and space frames as well as more conventional structural designs. Much apparatus is available for generating loads and for sensing and measuring the stresses, strains, deflections, and accelerations which result in the models.

The *Materials Research Laboratory* staff includes civil, chemical, and mechanical engineers, metallurgists, and electronics specialists; its mission is research on materials which are useful to the practice of civil engineering. Among the latter are concrete and cementitious compounds, metallic reinforcements, metals, natural and synthetic polymers, glasses, asphalt and bituminous materials, wood, and various composites containing combinations of these. The research programs are directed toward understanding of composition-structure-property relationships, the control of properties for enhanced usefulness, and the experimental measurement of properties to facilitate best engineering design. As a consequence, considerable and varied equipment for the production, fabrication, and evaluation of materials is available, with new apparatus continually being developed. Cooperation exists with other similar groups in the Institute.

The *Civil Engineering Systems Laboratory* is an intra-department organization which serves as a focus for the interest in systems analysis and design in all areas of civil engineering. The Laboratory also maintains and operates the Department's computing facilities. These include an IBM 1130 computer to which students have direct access, located in a classroom equipped with closed-circuit TV for group demonstration; and an IBM System/360, Model 40 which is used both for research and student Course work. In addition, remote console facilities for direct communication with the IBM 7094 in the M.I.T. Information Processing Services Center are available in the Department for student use in the time-shared mode of operation. Also available are on-line plotting devices and a scope for graphical computer input-output. Of particular interest to the laboratory is the development of computer programming systems for machine-aided engineering design. Advanced languages and systems specifically developed for student computer use are available. In addition, research is being conducted on computer-aided design in fields such as structures, soils, hydrology, and transportation.

INTERDISCIPLINARY PROGRAMS

By design, the curriculum of the Department presents many opportunities for interdisciplinary programs, both undergraduate and graduate, and only rarely do any two of them coincide exactly. For example, a student primarily but not exclusively interested in civil engineering may pursue valuable supplementary work in planning, architecture, management, computers, mathematics, economics, political science, and the life and earth sciences. Or, if his interests are more definitely technical, combinations with mechanical, electrical, nuclear, or chemical engineering are available. Well defined subject areas within the general domain of civil engineering may be followed by interdepartmental programs, including materials, transportation, construction management, structures, operations research, computers and information systems, water resources, building technology, and earth physics. In short, each student's educational and research program may be explicitly arranged to reflect best his personal motives and professional goals, whether they are intensive or extensive in nature.

THE INTER-AMERICAN PROGRAM IN CIVIL ENGINEERING

In cooperation with selected universities in Latin America, research programs on civil engineering problems are performed by small groups composed of M.I.T. and Latin American faculty and students; both undergraduate and graduate students of the Department may be eligible to participate in these activities. Each project extends over an appreciable time interval, thus affording opportunities for location field studies in Latin America where the social, economic, political, and technical factors involved in the problems may be observed. Experimental work, model studies, design evaluations, and other research activities are performed at the Institute, where the entire group is located during the major portion of the project.

The projects studied may be characterized as ones profiting from the use of modern technology and new scientific information in a research manner; the results of the work are presented in seminars in Latin America, to which interested local groups are invited.

THE UNDERGRADUATE PROGRAM

Civil Engineering (Course I)

The Department of Civil Engineering offers two undergraduate curricula for students seeking a strong base for careers in civil engineering or related fields. The first curriculum, which leads to the degree of Bachelor of Science in Civil Engineering, is designed for students interested in the technical and scientific aspects of engineering construction. The second curriculum, which leads to the degree of Bachelor of Science, is designed for students having a broad, well defined educational goal, the attainment of which requires a specially formulated course of study.

Each of these curricula provides sufficient flexibility to permit each student to develop his own special interests either within the Department or through subjects offered by other departments. Undergraduates are encouraged to participate in the research and development activities of the Department and in many cases can obtain degree credit for such work.

With the exception of two subjects in basic physics and mathematics, all core subjects are taught by faculty of the Department using examples drawn from their own experiences. However, the subjects in mechanics, materials, geology and mathematics are compatible, and when necessary interchangeable, with corresponding subjects offered by other departments.

THE DEGREE: BACHELOR OF SCIENCE IN CIVIL ENGINEERING

The curriculum centers about a core which includes a firm grounding in mechanics, materials and physical geology; advanced mathematics including statistics and probability; study and use of computers as computational and information systems; and work in the three technical areas basic to construction — structures, fluids, and soils. The curriculum is capped by a "projects" subject in which students develop solutions to actual civil engineering problems drawn from the recent and current experiences of the senior faculty.

The curriculum also permits great flexibility with regard to scheduling. An entering student who has already decided upon a career in civil engineering is able to complete one-half of the Departmental Program by the end of his second year, thus permitting many professional electives during the third and fourth years. On the other hand, an undergraduate who wishes to delay his career decision will find it possible to compress as many as ten of the subjects of the Departmental Program into the third and fourth years.

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CURRICULUM FOR S.B. DEGREE IN CIVIL ENGINEERING

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)					
	Specific science and humanities and social science subjects.				**128**
	ECONOMIC PRINCIPLES I (14.01) is required in the upperclass humanities and social science program.				
	The subjects 1.01, 8.03T and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement[1] (see the list on page 49)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects[2]				
1.00	INFORMATION SYSTEMS	3	3	6	
1.01	ENGINEERING MECHANICS	4	0	8	
1.02	ENGINEERING MATERIALS	3	3	6	
1.03	ENGINEERING ANALYSIS	4	0	8	
1.04	STRUCTURAL ANALYSIS AND DESIGN I	3	3	6	
1.05	FLUID DYNAMICS	3	3	6	
1.06	SOIL MECHANICS	3	3	6	
1.07	ANALYSIS OF UNCERTAINTY	3	1	5	
1.08	GEOTECHNOLOGY	3	3	6	
1.09	CIVIL ENGINEERING	0	6	12	
8.03T	PHYSICS III	5	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					147
	Unrestricted Electives[3]				**73**
Total units required for the S.B. degree					**360**

[1] 1.10 CIVIL ENGINEERING LABORATORY is recommended but not required.

[2] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

[3] Schedules of students in Course I may always be arranged to leave available 12 units of unrestricted elective in the second year.

THE DEGREE: BACHELOR OF SCIENCE

The core requirements of this curriculum are divided into required subjects and planned electives. The required subjects provide firm grounding in mathematics, in mechanics and materials, and in the use of computers as computational and information systems. By means of the planned electives, the student develops his own program for achieving a well defined educational goal. Under this program, for example, students interested in urban affairs or in transportation systems may develop sequences of planned electives in systems analysis, city planning, and political science.

Students planning to follow this curriculum must submit to the Department, no later than the end of the fall term of the Junior year, a statement of their educational goal and a list of the planned electives to achieve this goal. Students should at an earlier date discuss their interests and intended programs with one or more of the faculty of the Department.

CURRICULUM FOR S.B. DEGREE

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)					
	Specific science and humanities and social science subjects.				**128**
	ECONOMIC PRINCIPLES (14.01) is required in the upperclass humanities and social science program.				
	The Science Distribution Requirement will be satisfied by 1.01 and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 48) totaling				**12**
	Laboratory Requirement[1] (see the list on page 49)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects[2]				
1.00	INFORMATION SYSTEMS	3	3	6	
1.01	ENGINEERING MECHANICS	4	0	8	
1.02	ENGINEERING MATERIALS	3	3	6	
1.07	ANALYSIS OF UNCERTAINTY	3	1	5	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					57
	Planned Electives				
	A coherent selection of at least eight subjects, at least three of which must be subjects in Civil Engineering, which is aimed at a well defined educational goal. The planned electives are to be agreed upon between the student and a designated Faculty Counselor of the Department of Civil Engineering			at least	**84**
	Unrestricted Electives			up to	**67**
Total units required for the S.B. degree					**360**

[1] 1.10 CIVIL ENGINEERING LABORATORY is recommended but not required.

[2] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

ELECTIVE SUBJECTS

Undergraduate elective subjects offered by the Department include the following:

1.51	STRUCTURAL ANALYSIS AND DESIGN	3	2	5
1.60	APPLIED FLUID DYNAMICS	3	0	6

By the fourth year, students will have the prerequisites for a variety of graduate subjects offered by the Department in the applied earth sciences, hydrodynamics and water resources, soils, structures, materials, systems, transportation, and construction management. Descriptions of typical sequences of subjects in these areas may be obtained from Faculty Counselors.

Students wishing to work closely with a faculty member in his research may obtain permission to register for thesis or to enroll in SPECIAL STUDIES IN CIVIL ENGINEERING (1.99).

Students are encouraged to consider appropriate subjects offered by other departments as part of their elective programs.

GRADUATE STUDY IN CIVIL ENGINEERING

The Graduate Degrees

The Department grants the following advanced degrees:

Master of Science in Civil Engineering
Civil Engineer
Materials Engineer
Doctor of Science
Doctor of Philosophy

The general requirements for the various degrees are indicated in Section 3.

Entrance Requirements for Graduate Study

In addition to the admission requirements noted in Section 3, applicants must present evidence of appropriate training for graduate study in the areas of their interest, though this preparation need not have been in Civil Engineering. Normally students may make up deficiencies in prerequisites for graduate subjects while pursuing a program of graduate work; prerequisite subjects are indicated with the description of each subject in this Catalogue.

Fields of Advanced Study

The Department has integrated programs for graduate study in the following areas: the applied earth sciences, hydrodynamics and water resources, soil mechanics, structures and structural mechanics, materials, civil engineering systems, transportation systems, urban systems, engineering construction, and operations. Each of these is described briefly below. For major fields for doctoral theses, students should refer to the Civil Engineering list in Section 3 of this Catalogue. Fields other than those listed must be approved by the Department Graduate Registration Officer and by the Dean of the Graduate School.

THE APPLIED EARTH SCIENCES

Extensive departmental involvement with the behavior of near-surface earth materials, the microstructure of natural dynamic processes, and the interactions of these with constructed facilities has led to the development of new interdisciplinary research and graduate teaching programs in the applied earth sciences. The primary efforts are being directed toward a synthesis of fluid mechanics, soil mechanics, rock mechanics, and geology. The Department's work in these areas is described in more detail below under the headings *Hydrodynamics and Water Resources* and *Soil Mechanics*.

HYDRODYNAMICS AND WATER RESOURCES

Vital problems of Civil Engineering exist in the areas of hydrodynamics, hydrology and water resources design and development. Basic applications of fluid mechanics and of systems methodology are involved in hydraulic engineering, pollution abatement, coastal and ocean engineering, hydrologic analysis and water resources planning.

Modern developments in hydrodynamics deal with turbulence, boundary layers, free surface flow, wave motion, diffusion processes, sedimentation and flow in porous media.

The planning and development of water resources is treated from the standpoint of analysis and synthesis of hydraulic and hydrologic systems as well as of optimum integration of physical, economic and social factors.

Water quality is covered with regard to the effect of man's activities in utilizing and polluting water sources and to methods of restoring or maintaining desirable characteristics.

An extensive research program in the Hydrodynamics Laboratory is closely coupled with the educational offerings and at present includes the following areas:
Transformation and shoaling of waves in nonuniform channels, tidal dynamics in estuaries and sea-level canals, interaction of submerged bodies and fluid interfaces, wave forces on offshore structures, mechanics of stratified flow, dispersion, circulation and mixing processes in lakes, rivers and estuaries, heat absorption and storage in lakes, thermal pollution, flow and dispersion in porous media, sediment transport and erosion of cohesive materials, resistance and turbulence phenomena in fluid suspensions, cavitation control on rough boundaries, analysis and synthesis of hydrologic systems, water distribution networks and regional development of water resource systems.

SOIL MECHANICS

The civil engineer uses soil as a foundation material for a wide variety of structures, such as buildings, bridges, pavements, and retaining walls, and also uses it as a construction material for such things as embankments, dams, roads, and canal linings. The graduate program in soils emphasizes the development and evaluation of techniques for practical design, and is supported by major efforts in the analysis of deformation, stability, and flow problems, the measurement of the engineering properties of soil in the field and laboratory, including basic research on the physicochemical properties of soils, and the measurement and evaluation of

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the field behavior of soils during and after construction.

In addition to the comprehensive treatment of theoretical soil mechanics, soil properties, and applied soil mechanics, there are advanced subjects in soil dynamics, soil technology, engineering geology, and rock mechanics. These subjects, together with thesis research and other studies utilizing the unique laboratory facilities of the Department, offer students excellent opportunities to work closely with the faculty in the study of such problems as the behavior of embankments on soft ground, the behavior of deep braced cuts, the measurement and analysis of foundations of buildings on the M.I.T. campus, the use of theoretical and computer techniques to solve stress distribution, deformation, stability, and flow problems, the behavior of stabilized soils, the behavior of sand under vibratory and earthquake loading, the behavior of jointed rock masses, frost action, and the physicochemical behavior of clay-water systems.

STRUCTURES AND STRUCTURAL MECHANICS

The program offered in structures encompasses the range of activities involved in the design of complete systems such as buildings, bridges, towers, and various industrial facilities. It includes study in the theory of structural mechanics, in the conception and planning of structural systems, in advanced design techniques, and in the optimization of design with regard to the use of materials, construction costs, and operating efficiency.

The research program, in which students naturally become involved, closely parallels the academic subject offerings. In structural mechanics, current work includes theoretical developments in shell theory, the inelastic behavior of structures, and structural dynamics including design to resist earthquakes. The complete design process is being investigated through studies of probabilistic approaches to design, structural optimization, and the use of computers in design. New design techniques are being developed through the use of finite element methods for plates and shells, the use of model analysis for complex structures, and the creation of computer languages for structural design. In addition, new structural systems are being devised together with the construction techniques which will make them feasible.

MATERIALS

Civil engineers are the largest users of materials in any area of technology and the entire field of structural materials is undergoing rapid changes at the present time. These two facts impart unique characteristics to our teaching and research programs related to materials. On the one hand, the origin of properties, in terms of composition and internal structure, must be clearly understood. Equally important is the ability to utilize these properties, effectively, economically and imaginatively, to fulfill engineering needs. The property-composition-internal-structure relationships are treated in a number of fundamental subjects, some of which deal with broad classes or families of materials to illustrate the principles involved. Related to these subjects are research programs employing basic techniques and tools such as optical and electron microscopy, x-ray diffraction, single crystal studies and microstructural examinations; students acquire operational skill with the latter both through their Course work and in their research activities.

The application of materials to civil engineering needs, in a rational and quantitative fashion, represents the second main component of our effort. In this area are found subjects and research dealing with structural composites, fracture mechanics, viscoelasticity and rheology, mechanics of materials and the mechanical behavior of metals. Again, considerable reinforcement between teaching and research takes place and the most modern testing and computational equipment and techniques are employed.

Students are also given opportunity to pursue studies in materials engineering, under interdepartmental supervision, leading to the degrees of Materials Engineer or Doctor of Science or Doctor of Philosophy. There is no standard curriculum in this field, and each student arranges a program of study and research uniquely suited to his interests and professional goals.

CIVIL ENGINEERING SYSTEMS

Advanced study and research in civil engineering systems emphasizes the application of modern mathematical, computer, and operations research methods to problems in engineering management systems, water resources, structures, and construction management systems. Principal attention is directed to new approaches to solving civil engineering problems at the project and operational system level. Advanced computer methods, operational systems analysis, information systems, and man-machine communications are important areas of

focus. Current research in the area of computers includes problem-oriented computer programming languages, graphical data processing, computer methods of location and design, simulation, and time-shared computer usage.

TRANSPORTATION SYSTEMS

The essential focus of teaching and research in transportation is on systems planning, especially multimode systems. The program builds upon basic knowledge of the properties of transportation systems components, and the ability to analyze interactions among these components and between the transportation system and its environment. The basic approach is that of rational decision making about engineered systems, using where appropriate such techniques of systems analysis as economics, mathematical optimization, and computer models. Close relation to an extensive body of research supports and stimulates the academic program. Subjects of instruction offered include fundamentals of transportation systems, transportation systems analysis, transport systems design, urban transportation systems, flight transportation, traffic flow theory, decision theory, system simulations, mathematical programming, network flow, economic analysis, probabilistic analysis, and substantive applications to highway, air, rail, and sea transport. The Transportation Systems Division works in close relation to the Systems Laboratory in both teaching and research. Collaboration is encouraged with other groups at the Institute whose interest is related to transportation.

CONSTRUCTION AND OPERATIONS

Construction is the focal point of civil engineering, where all the specialists in civil engineering are drawn inevitably together and where the many diverse aspects of civil engineering — research, planning, analysis, and design — find their common purpose.

Several major research projects in the Department of Civil Engineering are centered around construction. The approach is to predict some aspect of the performance of a structure on the basis of theory and laboratory or field tests, or both; instrument the structure; observe the behavior of the structure during and after construction; and evaluate the performance of the structure and the techniques used for predicting the performance. The many students who work on the projects have the opportunity to learn firsthand about the problems of construction. The research leads to the improvement of old techniques or the development of new techniques of analysis, testing, and construction, and in this way not only advances the profession but has an immediate impact on the formal subjects taught in the Department.

URBAN SYSTEMS ENGINEERING

A majority of civil engineering projects are located in metropolitan areas. Their design must therefore take into consideration not only the physical loads that will be imposed upon them, but also the strong interaction between these facilities and the complex economic and social forces of the urban environment.

Urban systems engineering applies modern computer-aided analytic techniques, tempered by an appreciation for relevant human issues, to the creative solution of urban civil engineering problems. The academic program thus integrates three complementary lines of study: methods of systems analysis, an application area such as transportation or water resources, and the urban context.

Research in urban systems engineering is supported by the interdepartmental Urban Systems Laboratory and the Civil Engineering Systems Laboratory. The work is closely tied to the educational program and current developments are rapidly brought into the classroom. Last year, for example, students worked on the layout of a proposed quarter-billion-dollar municipal water supply network.

Research Assistants

The research of the Department is an integral part of the study program, and approximately one hundred graduate students each year receive appointments as research assistants. In addition to the financial support so gained, such appointments provide valuable educational experience and outstanding thesis opportunities. Information about these appointments, and other forms of financial assistance, may be obtained by writing to the Head of the Department; but consideration for awards cannot be given before students have been assured of admission to the Graduate School.

Engineering

DEPARTMENT OF ELECTRICAL ENGINEERING

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Engineering

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ALAN VICTOR OPPENHEIM, SC.D. (*Absent*)
Assistant Professor of Electrical Engineering
RONALD RICHARD PARKER, SC.D.
Assistant Professor of Electrical Engineering
KALLURI RAMALINGASARMA, PH.D.
Assistant Professor of Electrical Engineering (Visiting)
IAN BURTON RHODES, PH.D.
Assistant Professor of Electrical Engineering
JAMES KERR ROBERGE, SC.D.
Assistant Professor of Electrical Engineering
JEROME HOWARD SALTZER, SC.D.
Assistant Professor of Electrical Engineering
JOEL ELLIOT SCHINDALL, PH.D.
Assistant Professor of Electrical Engineering
STEPHEN DAVID SENTURIA, PH.D.
Assistant Professor of Electrical Engineering
CHARLES VINCENT SMITH, JR., SC.D.
Assistant Professor of Electrical Engineering
DANIEL LAFAYETTE SMYTHE, JR., PH.D.
Assistant Professor of Electrical Engineering
DONALD LEE SNYDER, SC.D.
Assistant Professor of Electrical Engineering
RICHARD NELSON SPANN, PH.D.
Assistant Professor of Electrical Engineering
DAVID HUDSON STAELIN, SC.D. (*Absent*)
Assistant Professor of Electrical Engineering
KEITH I. THOMASSEN, PH.D.
Assistant Professor of Electrical Engineering
JAMES NEWMAN WALPOLE, PH.D.
Assistant Professor of Electrical Engineering
MICHAEL LEWIS WIEDERHOLD, PH.D.
Assistant Professor of Electrical Engineering
JAN CAMIEL WILLEMS, PH.D.
Assistant Professor of Electrical Engineering
GERALD LOOMIS WILSON, SC.D.
Assistant Professor of Electrical Engineering
ROBERT DONALD YATES, PH.D.
Assistant Professor of Electrical Engineering

Administrative Officer

JOHN AVERY TUCKER, M.ENG.

Lecturers

RICHARD HARRISON BAKER, S.M.
JORDAN JAY BARUCH, SC.D.
LEO LEROY BERANEK, SC.D.
GODFREY THOMAS COATE, M.S.
NATHANIEL I. DURLACH, M.A.
BERNARD GOLD, D.E.E.

ROBERT DILWYN HALL, PH.D.
DONALD RUSSELL HARING, SC.D.
JESSE CLOPTON JAMES, PH.D.
NELSON YUAN-SHENG KIANG, PH.D.
ALEXANDER KUSKO, SC.D.
RICHARD GWYN MILLS, S.M.
ROBERT HARVEY RINES, S.B., LL.B.
DOUGLAS TAYLOR ROSS, S.M.
ALLAN CARTER SCHELL, SC.D.
HERBERT MARTIN TEAGER, SC.D.
OLEH JOHN TRETIAK, SC.D.
JOHN ERWIN WARD, S.M.

Instructors

WALTER HENRY BERNINGER, S.M.
BARRY ALLEN BLESSER, S.M.
ARTHUR ALLAN BUSHKIN, S.M.
HARRY STEVEN COLBURN, S.M.
RICHARD JAMES DIEPHUIS, S.M.
LANSING HATFIELD, E.E.
KEITH MILLICAN JOSEPH, S.M.
JOHN GABRIEL KASSAKIAN, E.E.
RICHARD ROBERT KURTH, S.M.
RICHARD CHARLES LARSON, E.E.
SUHAS SHRIKRISHNA PATIL, S.M.
JAMES ALAN ROME, E.E.
CHARLES LEWIS SEITZ, III, S.M.
CARLTON EDWARD SPECK, S.M.
ALTON PARKER TRIPP, JR., E.E.
IAN THEODORE YOUNG, S.M.

Administrative Assistants

MAX MORTON BYER
HORACE McNUTT SMITH, JR., B.A.
DOROTHY YOUNG

Non-Resident Instructors

STANLEY JASON BECKER, PH.D.
LEO HELLERMAN, PH.D.
PAUL HENDERSON KURTZ, M.S.
BERNARD JOSEPH LECHNER, B.S.E.E.
RICHARD CARL LEVINE, SC.D.
CABELL NICHOLAS PRYOR, JR., S.M.
LAWRENCE RICHARD RABINER, PH.D.
LEONARD RABINS, M.S.
BRUCE B. ROBINSON, PH.D.
HAROLD STARAS, PH.D.
GEORGE NORMAN TRYTTEN, PH.D.

Research Associates

KENNETH RUSSELL INGHAM, M.A.
ARTHUR LINZ, PH.D.
DEAN ARNOLD POWERS, E.E.
DONALD HARLEY STEINBRECHER, PH.D.

Professors Emeriti

HERBERT BRISTOL DWIGHT, D.SC.
Professor of Electrical Machinery, Emeritus

MARCY EAGER, S.B.
Associate Professor of Electrical Engineering, Emeritus

HAROLD EUGENE EDGERTON, SC.D., D.ENG.
Institute Professor, Emeritus;
Professor of Electrical Measurements, Emeritus

RICHARD HENRY FRAZIER, S.M.
Professor of Electromechanics, Emeritus; Senior Lecturer

MURRAY FRANK GARDNER, S.M.
Professor of Electrical Engineering, Emeritus

ERNST ADOLPH GUILLEMIN, PH.D.
Professor of Electrical Engineering, Emeritus

HAROLD LOCKE HAZEN, SC.D.
Professor of Electrical Engineering, Emeritus;
Dean of the Graduate School, Emeritus,
Foreign Study Adviser

PARRY MOON, S.M.
Associate Professor of Electrical Engineering, Emeritus

ALEXANDER SMAKULA, PH.D.
Professor of Crystal Physics, Emeritus;
Senior Lecturer

ARTHUR ROBERT VON HIPPEL, PH.D.
Institute Professor, Emeritus;
Professor of Electrophysics, Emeritus

KARL LELAND WILDES, S.M.
Professor of Electrical Engineering, Emeritus

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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. Its products and services directly influence the daily living of most of the world's population. Its generators, motors, and other energy-processing devices provide the large quantities of inexpensive power needed in the industrialized and developing modern world. Its instruments for detecting, observing, and measuring electrical signals give it a unique role in supporting the advance of all other branches of science and engineering. Its conceptual models of detection, communication, and automatic control have influenced the development of such fields as economics, industrial management, psychology, and linguistics. Most recently its digital computers have revolutionized experimental techniques throughout the natural and behavioral sciences, engineering, and management and have provided models and tools for the study of the brain.

In a field with the rapid rate of change of modern electric technology, no one can describe with confidence the devices and systems of 15 years hence. But it seems very likely that their development and understanding will require a knowledge of electromagnetic fields and waves, that their performance will be limited by considerations of mechanics and thermodynamics, and that they will exploit the quantum-mechanically based electrical and magnetic properties of matter. It also seems likely that the systems will handle signals in the presence of noise and that the mathematical apparatus for dealing with signals, noise, and stability will be useful. The undergraduate and graduate curricula are based on such assumptions. In the undergraduate core curriculum, and in many of the graduate subjects, the emphasis is on the physical and mathematical principles and the techniques of applying them to real problems. In addition, however, elective subjects dealing with specialized techniques in a variety of fields are offered.

THE UNDERGRADUATE CURRICULA

The Department offers four undergraduate programs, two in Electrical Engineering (Course VI, Program 1 and Course VI-A, Program 1) and two in Electrical Science and Engineering (Course VI, Program 2 and Course VI-A, Program 2). The two VI-A programs permit the student to combine study with industrial engineering practice. In either program, a student who is admitted to graduate work may combine the Bachelor's and Master's thesis and receive the Bachelor of Science and the Master of Science degrees simultaneously at the end of five years of study. The common objective of all of these programs is to provide a broad and deep foundation on which can be based a large number of interesting careers.

Students in Program 1 are well prepared for graduate study in electrical engineering or for industrial careers. Through a proper selection of elective subjects they may get a good start in a specialized branch of electrical engineering or they may prepare themselves for graduate study in engineering or in such fields as physics, mathematics, industrial management, and the social sciences.

Program 2 is designed for students who are planning research-oriented or teaching careers. They are expected to study more deeply in the basic sciences (biology, mathematics, physics, etc.) in order to provide the necessary foundation for their future graduate study and research. Graduates of both programs have gone on to graduate work in many fields, from mathematics and physics to law and medicine.

Both Programs 1 and 2 require two terms of mathematics and two terms of physics beyond the General Institute Requirements, introducing the student to differential equations, theory of functions of a complex variable, electricity and magnetism, and quantum mechanics. The physics and mathematics background is used in a group of seven core electrical engineering subjects in linear circuits, electronics, electromagnetic fields and waves, signal analysis and transform theory, lumped and continuous electromechanical systems, and statistical mechanics and thermodynamics. These core subjects use lecture demonstrations, small sections, carefully developed homework assignments, and individual weekly conferences with each student to make sure that the points brought out in the homework are fully mastered.

The Electrical Engineering programs allow the student to take a considerable number of unrestricted elective subjects without overload. Students may use these as they see fit: they may take additional humanities subjects, science subjects, or use them to get a start in specialized branches of electrical engineering. To provide students with a chance to specialize in several of

the current disciplines of electrical engineering, and to bring them into contact with current graduate research in these areas, several sequences of electrical engineering electives have been developed.

The different engineering disciplines which students may enter through these elective sequences are: control, computer science, digital systems, electronic materials and devices, electromagnetics and dynamics, communications, and bioengineering. Students should consult with their Faculty Counselors about these specialized elective sequences.

Electrical Engineering (Course VI)

PROGRAM 1. ELECTRICAL ENGINEERING

This program leads to the degree of Bachelor of Science in Electrical Engineering. The curriculum, consisting of a core of required subjects and a number of elective subjects, allows a student to prepare himself for an industrial career or for graduate study.

Since the General Institute Requirements for Science Distribution subjects and Laboratory are met by the program, a total of 64 units of upperclass elective time is available which the student may use for a number of purposes. He may, for example, elect eight additional upperclass subjects in the humanities and social sciences. He may take a substantial minor program in industrial management. He may elect elementary foreign language subjects as well as advanced subjects in physics, mathematics, and electrical engineering, to prepare for a future doctoral program. He may take electives in transistor electronics, communications, control, computer systems, probability, and instrumentation to prepare for a career in the engineering of large-scale systems. He may explore fields such as biology, psychology, and linguistics, to develop an understanding of communications in a context which includes both men and machines.

The Department of Electrical Engineering recommends that all undergraduates get some industrial experience during their program at M.I.T. There are two reasons for this recommendation. First, many aspects of the education of an engineer can be learned much more effectively and realistically on a job than by listening to lectures about them in the classroom. Second, most students get a great deal of pleasure from the discovery that the knowledge they have gained at M.I.T., which may have seemed rather abstract, does in fact help them to solve real and important engineering problems.

The curriculum requirements for the Electrical Engineering Program are listed below.

PROGRAM 1. ELECTRICAL ENGINEERING CURRICULUM (COURSE VI)

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)					
	Specific science and humanities and social science subjects.				**128**
	ECONOMIC PRINCIPLES I (14.01) is recommended in the upperclass humanities and social science program.				
	The subjects 6.01, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	The subjects 6.70 and 6.71, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Institute Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
6.01	[2]INTRODUCTORY NETWORK THEORY	4	0	8	
6.02	ELECTRONIC DEVICES AND CIRCUITS	4	0	8	
6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.70	ELECTRONIC COMPONENTS AND MEASUREMENTS	1	4	1	
6.71	[3]ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
8.03T	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
18.034	[2]DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	[4]THESIS		12		
					120
	Restricted Electives[1]				
	Two of the following subjects				
6.06	FIELDS, FORCES AND MOTION	3	0	9	
6.07	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.08	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
			24		
	Laboratory[1]				
	Any subject selected from the list below		12		
					36
6.711	DIGITAL SYSTEMS PROJECT LABORATORY	2	8	2	
6.712	BIOELECTRONICS PROJECT LABORATORY	2	8	2	
6.714	ELECTRONIC LIGHT MEASUREMENTS PROJECT LABORATORY	2	8	2	
6.715	POWER SYSTEMS PROJECT LABORATORY	2	8	2	
6.716	PARTICLE OPTICS PROJECT LABORATORY	2	8	2	
6.717	AUDIO FREQUENCY COMMUNICATIONS PROJECT LABORATORY	2	8	2	
6.718	VHF CIRCUITS PROJECT LABORATORY	2	8	2	
6.719	SEMICONDUCTOR DEVICES AND CIRCUITS PROJECT LABORATORY	2	8	2	
6.721	ADVANCED DIGITAL SYSTEMS PROJECT LABORATORY	2	8	2	
6.722	MODERN OPTICS PROJECT LABORATORY	2	8	2	
					76
	Unrestricted Electives[5]				
Total units required for the S.B. degree					**360**

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[1] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

[2] Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4–0–8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4–0–8) in substitution for 6.01 and 18.034. Note that 6.002 does not satisfy the Science Distribution Requirement.

[3] In lieu of 6.71 the following laboratories may be taken: 6.215T FEEDBACK CONTROL LABORATORY (at least 6 units) or 6.81 ELECTRICAL ENGINEERING LABORATORY (at least 6 units) or another Project Laboratory or a subject from the list of Institute Laboratory Subjects (see page 49). Note that the following subjects do not satisfy the Institute Laboratory Requirement: 6.215T, 6.81, 6.721, 6.722.

[4] A thesis of at least 12 units is required. Not more than 30 units of thesis credit can be included in the minimum of 360 units required for the S.B. degree.

[5] Schedules of students in Course VI, Program 1, may always be arranged to leave available 24 units of unrestricted elective in the second year.

The above requirements are not rigid. Some variations are routinely permitted, while others are considered on an individual basis. Well-motivated substitutions of substantially equivalent subjects are usually approved. Students may request substantial changes in program which involve more than substitution in kind. Departmental approval will be granted in general only to well-prepared students, whose proposed programs are comparable to the curriculum listed above in breadth, depth, and integrated approach to a well-defined educational objective.

PROGRAM 2. ELECTRICAL SCIENCE AND ENGINEERING

This program in Electrical Science and Engineering is offered for a selected group of students who show sufficient interest and ability to make it likely that they will continue their education through the doctorate. The subjects parallel the subjects in Program 1 but are characterized by greater depth. Students are expected to strengthen their background in the fundamental – and engineering – sciences by suitable choice of electives. Since most students in this program will be doing thesis work in graduate school, 12 units of seminar are used to satisfy the departmental requirement of a thesis or project for the Bachelor of Science degree. However, a student may undertake a Bachelor's thesis instead of the seminar, if he wishes.

New subjects or approaches are likely to be tried out first in Program 2. The challenge of the program attracts an excellent student body, and it is expected that students will maintain high academic standards.

Students normally apply for admission to Program 2 by interview at the end of the first year or shortly before Registration Day at the beginning of the second year. Transfer students or others well prepared in mathematics and physics who have completed the work of the second year of Program 1 may be admitted at the beginning of the third year.

Because they are likely to be engaged in a seven- or eight-year continuous educational program, Program 2 students are especially urged to gain some industrial experience, either through summer jobs or through Program 2 of Course VI-A described below.

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.

PROGRAM 2. ELECTRICAL SCIENCE AND ENGINEERING CURRICULUM (COURSE VI)

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)				
	Specific science and humanities and social science subjects.			**128**
	ECONOMIC PRINCIPLES I (14.01) is recommended in the upperclass humanities and social science program.			
	The subjects 6.013, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.			
	The subjects 6.70 and 6.71, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Institute Laboratory Requirement.			
DEPARTMENTAL PROGRAM				
	Required Subjects[1]			
6.013	[2]INTRODUCTORY NETWORK THEORY	4	0	8
6.023	ELECTRONIC DEVICES AND CIRCUITS	4	0	8
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8
6.053	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8
6.11	[4]PROJECT SEMINAR	2	0	4
6.12	[4]PROJECT SEMINAR	2	0	4
6.70	ELECTRONIC COMPONENTS AND MEASUREMENTS	1	4	1
6.71	[3]ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1
8.03T	PHYSICS III	5	0	7
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7
18.034	[2]DIFFERENTIAL EQUATIONS	3	0	9
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9
				120
	Restricted Electives[1]			
	Two of the following subjects			
6.063	FIELDS, FORCES, AND MOTION	3	0	9
6.073	ENERGY TRANSMISSION AND RADIATION	4	0	8

(*continued*)

Restricted Electives *(continued)*				
6.083	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8
	Laboratory[1]			24
	Any subject selected from the list of laboratory subjects given under Course VI, Program 1			12
				36
	Unrestricted Electives[5,6]			**76**
Total units required for the S.B. degree				**360**

[1] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

[2] Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4–0–8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4–0–8) in substitution for 6.013 and 18.034. Note that 6.002 does not satisfy the Science Distribution Requirement.

[3] In lieu of 6.71 the following laboratories may be taken: 6.215T FEEDBACK CONTROL LABORATORY (at least 6 units) or 6.81 ELECTRICAL ENGINEERING LABORATORY (at least 6 units) or another Project Laboratory or a subject from the list of Institute Laboratory Subjects (see page 49). Note that the following subjects do not satisfy the Institute Laboratory Requirement: 6.215T, 6.81, 6.721, 6.722.

[4] These subjects are taken in place of the Departmental S.B. thesis requirement.

[5] Schedules of students in Course VI, Program 2, may always be arranged to leave available 24 units of unrestricted elective in the second year.

[6] Subjects in materials and probability — e.g., 6.13, 6.28, and 18.18 — are particularly suitable adjuncts to this program.

The comments about variation in requirements following the Program 1 curriculum apply to Program 2 also. Well-conceived proposals by students in Program 2 embodying substantial changes have usually received departmental approval.

Electrical Engineering (Course VI-A)

The VI-A Program provides the student with a way of gaining industrial and research experience concurrently with his undergraduate studies, through a series of organized plant assignments interleaved with regular study at M.I.T. Students in the VI-A programs are likely to receive more professionally rewarding assignments than the typical summer job may provide, because of continuing liaison between each participating company and a professor in the Department. The students can also spend more time on the job because the subjects taken while on job assignments and the academic credit received for plant experience help meet the degree requirements.

Second-year students in good standing in either program of Course VI may apply. The interviews with the cooperating companies are held in the spring. Applications may be made in the VI-A office early in the spring term. The Department cannot guarantee the acceptance of a student by one of the participating companies; typically most, but not all, of the interested students are placed. The program terminates in four years if the student leaves M.I.T. with a Bachelor of Science degree; if he is admitted to the Graduate School, the program continues through the fifth year. Admission to the Graduate School is based on the student's scholastic record and personal qualifications.

Course VI-A students who elect to pursue graduate study at M.I.T. are required to perform four terms of industrial practice. Three industrial-practice terms are normally required during the undergraduate program; in special cases, however, students who plan to leave M.I.T. upon receipt of their Bachelor of Science degree may omit the third practice term. On entering the VI-A Program, a student must agree to stay with one company through his Bachelor's and/or Master's degree.

Taken together, the participating companies cover substantially the entire spectrum of electrical technology and the electrical industry. Although a student is 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 industrial companies — such as the AVCO Corporation, General Electric Company, General Radio Company, Honeywell, Inc., International Business Machines Corporation, Radio Corporation of America, and Raytheon Company — provide experience in testing, design, development, and research in various areas of electronics, power, communications, control, and computation fields. The American Electric Power Corporation provides 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 experience in the development of communication apparatus, circuits, and equipment for the Bell Telephone System. The Air Force Cambridge Research Laboratories and the Naval Ordnance Laboratory provide opportunities to work with people from many technical disciplines, brought

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together in a large laboratory concerned with basic and applied research in many fields.

While at the plants, students are subject to the usual company regulations. They receive regular financial compensation for their work. During the practice periods, classes in prescribed academic subjects are held two evenings a week. At the conclusion of the program, students are not obligated to accept employment with the company, nor is the company obligated to offer employment.

These programs lead 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 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.

PROGRAM 1. ELECTRICAL ENGINEERING CURRICULUM (COURSE VI-A)

					Total units
GENERAL INSTITUTE REQUIREMENTS *(see page 99)*					
	Specific science and humanities and social science subjects.				**128**
	ECONOMIC PRINCIPLES I (14.01) is recommended in the upperclass humanities and social science program.				
	The subjects 6.01, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	The subjects 6.70 and 6.71, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Institute Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
6.01	[2]INTRODUCTORY NETWORK THEORY	4	0	8	
6.02	ELECTRONIC DEVICES AND CIRCUITS	4	0	8	
6.03	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.05	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.70	ELECTRONIC COMPONENTS AND MEASUREMENTS	1	4	1	
6.71	[3]ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
8.03T	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
18.034	[2]DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	[4]THESIS		12		
	[5]INDUSTRIAL PRACTICE		18		
					138
	Restricted Electives[1]				
	Two of the following subjects				
6.06	FIELDS, FORCES, AND MOTION	3	0	9	
6.07	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.08	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
				24	
	Laboratory[1]				
	Any subject selected from the list of laboratory subjects given under Course VI, Program 1			12	
					36
	Unrestricted Electives[6]				**60**
	Total units required for the S.B. degree				**362**

[1] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

[2] Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4–0–8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4–0–8) in substitution for 6.01 and 18.034. Note that 6.002 does not satisfy the Science Distribution Requirement.

[3] In lieu of 6.71 the following laboratories may be taken: 6.215T FEEDBACK CONTROL LABORATORY (at least 6 units) or 6.81 ELECTRICAL ENGINEERING LABORATORY (at least 6 units) or another Project Laboratory or a subject from the list of Institute Laboratory Subjects (see page 49). Note that the following subjects do not satisfy the Institute Laboratory Requirement: 6.215T, 6.81, 6.721, 6.722.

[4] A thesis of at least 12 units is required. Not more than 30 units of thesis credit can be included in the minimum of 360 units required for the S.B. degree. Students who continue studies for the S.M. degree and receive the S.M. and S.B. degrees simultaneously may substitute 12 units of additional elective for the S.B. thesis.

[5] Credit for Industrial Practice subjects is limited to a maximum of 27 units and a minimum of 18 units.

[6] Schedules of students in Course VI-A, Program 1, may always be arranged to leave available 24 units of unrestricted elective in the second year.

PROGRAM 2. ELECTRICAL SCIENCE AND ENGINEERING CURRICULUM (COURSE VI-A)

					Total units
GENERAL INSTITUTE REQUIREMENTS *(see page 99)*					
	Specific science and humanities and social science subjects				**128**
	ECONOMIC PRINCIPLES I (14.01) is recommended in the upperclass humanities and social science program.				
	The subjects 6.013, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	The subjects 6.70 and 6.71, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Institute Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
6.013	[2]INTRODUCTORY NETWORK THEORY	4	0	8	
6.023	ELECTRONIC DEVICES AND CIRCUITS	4	0	8	
6.033	ELECTROMAGNETIC FIELDS AND ENERGY	4	0	8	
6.053	CIRCUITS, SIGNALS, AND SYSTEMS	4	0	8	
6.70	ELECTRONIC COMPONENTS AND MEASUREMENTS	1	4	1	
6.71	[3]ELECTRONIC CIRCUITS AND SIGNALS LABORATORY	1	4	1	
8.03T	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
18.034	[2]DIFFERENTIAL EQUATIONS	3	0	9	

(continued)

Required Subjects *(continued)*					
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	INDUSTRIAL PRACTICE		18		
	[4]INDUSTRIAL PROJECT		12		
					138
	Restricted Electives[1]				
	Two of the following subjects				
6.063	FIELDS, FORCES, AND MOTION	3	0	9	
6.073	ENERGY TRANSMISSION AND RADIATION	4	0	8	
6.083	STATISTICAL MECHANICS AND THERMODYNAMICS	4	0	8	
			24		
	Laboratory[1]				
	Any subject selected from the list of laboratory subjects given under Course VI, Program 1		12		
					36
	Unrestricted Electives[5,6]				60
Total units required for the S.B. degree					362

[1] Under special circumstances, substitution of subjects of similar content may be permitted by petition to the Department.

[2] Students may elect 6.001 ELEMENTS, SYSTEMS, AND COMPUTATION I (4–0–8) and 6.002 ELEMENTS, SYSTEMS, AND COMPUTATION II (4–0–8) in substitution for 6.013 and 18.034. Note that 6.002 does not satisfy the Science Distribution Requirement.

[3] In lieu of 6.71 the following laboratories may be taken: 6.215T FEEDBACK CONTROL LABORATORY (at least 6 units) or 6.81 ELECTRICAL ENGINEERING LABORATORY (at least 6 units) or another Project Laboratory or a subject from the list of Institute Laboratory Subjects (see page 49). Note that the following subjects do not satisfy the Institute Laboratory Requirement: 6.215T, 6.81, 6.721, 6.722.

[4] The Industrial Project is taken in place of the Departmental S.B. thesis requirement.

[5] Schedules of students in Course VI-A, Program 2, may always be arranged to leave available 24 units of unrestricted elective in the second year.

[6] Subjects in materials and probability — e.g., 6.13, 6.28, and 18.18 — are particularly suitable adjuncts to this program.

GRADUATE STUDY IN ELECTRICAL ENGINEERING

The program of graduate education in the Department of Electrical Engineering has three aspects. First, a variety of classroom subjects in physics, mathematics, and fundamental fields of electrical engineering is offered to permit students to develop a strong theoretical background. Second, more specialized classroom and laboratory subjects and a wide variety of colloquia and seminars introduce the student to the problems of current interest in many fields of research, and to the techniques which may be useful in attacking them. Third, each candidate for any advanced degree conducts research under the direct supervision of a member of the Faculty and reports his results in a thesis.

Three advanced degree programs are offered. A well prepared student can obtain his Master of Science degree in one calendar year upon completion of a course of formal studies and the presentation of a satisfactory thesis. Students who need more classroom subjects before entering on thesis work, or who want to carry out a more substantial research or teaching program while gaining further graduate experience, may choose to complete their thesis by the end of a two-year program and receive the Electrical Engineer and the Master of Science degrees concurrently. The doctoral programs take three years or more to complete. Doctoral candidates are expected to perform thesis research which is a significant contribution to knowledge and to participate in the educational program of the Department. Most doctoral students complete the Master of Science degree requirements in the course of their doctoral programs.

There are no fixed programs of study for these degrees. Each student plans his program in consultation with his Graduate Counselor, a member of the Faculty whose professional field is related to the student's interest. As the program moves towards thesis research, it usually centers in one of a number of areas, each characterized by an active research program. Areas of interest in the Department which have active research programs and related graduate subjects include:

Active circuits, instrumentation, and systems
Automata theory and switching circuits
Communications in man-made and living systems
Computer systems
Control systems
Electromagnetic theory and antennas
Electromechanics, plasma dynamics, and electro- and magneto-fluid dynamics
Energy conversion devices and systems
High-voltage radiation engineering
Neurophysiology
Operations research and system engineering
Programming languages and artificial intelligence
Radio astronomy
Solid-state materials and devices
Stroboscopic photography and underwater sound

Besides the graduate subjects in Electrical Engineering, many students find it profitable to study subjects in other departments, such as Biology, Economics, Modern Languages and Linguistics, Management, Mathematics, Physics, and Psychology.

The informal seminar is an important mechanism for knitting together members of the various research groups. There are about 13 that

meet every week, and many other ad hoc seminars. In these, graduate students, faculty, and visitors report their research in an atmosphere of free discussion and criticism. For the new graduate student, these open seminars are excellent places to learn about the various research activities in the Department.

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. 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 the *Electronic Systems Laboratory* a program of research and development in control, computer technology and applications, and instrumentation is closely coupled with graduate study in these areas. Faculty, students and full-time staff are engaged in research on topics which include modern control theory; chemical-process control; high-speed vehicle control for ground and space environments; analytical and experimental studies of analog, digital, and analog-digital data-processing systems; logic design; the application of computers to electrical network and mechanical design; library information retrieval; research in man-machine communication devices and techniques for time-shared computers; research in computer programming; and electronic and microwave sensing systems for the measurement of physical quantities and for exploratory purposes in the aerospace environment. Taken together these research efforts provide excellent educational opportunities in system and circuit analysis and in the application of modern computational tools, design techniques, and circuit devices to a variety of dynamical systems.

The *Research Laboratory of Electronics* provides a basic research environment with participation of faculty and students from a dozen academic departments. Since the formation of the Laboratory in 1945, as an outgrowth of the M.I.T. Radiation Laboratory, the research program has evolved and broadened. At present, the activities of the Laboratory fall into three principal categories. These are general physics, plasma dynamics, and communication sciences. Among the research activities in general physics are: microwave, optical, and infrared spectroscopy, radio astronomy, molecular beam studies, microwave electronics, and lasers and coherent optics. The research in plasma dynamics includes basic studies of plasma physics and gaseous electronics, as well as applications such as controlled fusion for energy conversion, ion propulsion, and microwave devices.

The research in communication sciences involves studies of both living and man-made systems. The major areas of interest in communications bioengineering include communications biophysics, neurophysiology, speech communication, linguistics, and cognitive information processing. Other communications studies include information processing and transmission, statistical communication theory, artificial intelligence, circuit theory, and computer research.

Both graduate and undergraduate students participate in the full range of activities mentioned above.

Project MAC is an interdepartmental research effort. It supports research in areas such as computer languages, heuristic programming, automata theory, and display systems for convenient man-machine interaction. Both an object of research and the principal research tool in this work is a time-shared computer system which is being developed to make as easy as possible the effective real-time interaction of many users with a powerful computer.

The Continuum Electromechanics Group is concerned with the fundamental processes resulting from continuum electromechanical interactions and their engineering applications.

A group in the *High Voltage Research Laboratory* is concerned with the techniques of producing high-energy particles and radiation, and with their application to the needs of science, medicine, and industry.

A considerable segment of the departmental faculty is engaged in research in the area of solid-state science and engineering. Most of this work is carried on by groups affiliated with the *Center for Materials Science and Engineering*. *The Semiconductor Materials and Devices Groups* are concerned with problems which range from the fundamental physics of semiconductors to the engineering problems encountered in semiconductor device development and analysis, including some of those relating to integrated circuits and the allied use of computers. *The Micro-*

wave and Quantum Magnetics Group is involved in the study of magnetism in relation to crystal structure, in the development of new magnetic materials, and in the utilization of these materials in high-frequency and microwave electromagnetic and acoustic devices. *The Mass Spectroscopy Group* is measuring electron ionization cross sections, studying charged particle optics, and developing new experimental techniques. The single crystals needed for much of the foregoing research are provided by a *Crystal Physics Group*, which has its own active research program concerned with problems of crystal growth and the study of crystal structure and crystal imperfections. *The Materials Theory Group* is concerned with the theoretical description of the electrical, optical, and transport properties of semiconductors. In addition, it deals with the basic aspects of magnetic materials and superconductors.

Financial Aid

Studies toward an advanced degree can be supported by personal funds, by an award such as the National Science Foundation Fellowship which the student brings with him to M.I.T., by a fellowship or traineeship awarded by M.I.T., or by a graduate assistantship. Assistantships require participation in research or teaching in the Department or in one of the associated laboratories. Assistants may register for up to 24 units of scheduled classroom and laboratory work and may receive additional academic credit for their participation in the teaching or research program. Many assistants spend two years in a program which leads to the simultaneous award of the Master of Science and the Electrical Engineer degrees, and the Department encourages assistants to pursue such programs.

A brochure on *Research and Graduate Study in Electrical Engineering at M.I.T.*, describing research and teaching opportunities in detail, may be obtained from the Department.

Entrance Requirements for Graduate Study

The general requirements for admission are set forth in Section 3 of this Catalogue. In addition a candidate for an advanced degree in electrical engineering, if his undergraduate degree is in electrical engineering or a similar field, should present evidence that he has completed studies comparable in both breadth and depth to the undergraduate program described on the preceding pages. If, on the other hand, his undergraduate degree is in some other field (such as physics, mathematics, computer science, or biomedical engineering) no general requirements can be listed; the background of each such applicant will be studied carefully to see that he has the principal prerequisites deemed necessary for his probable graduate program. Applicants with non-electrical engineering backgrounds are encouraged to communicate directly with faculty members in their proposed area of study for advice and further details. In any case superior achievement in undergraduate mathematics and physics is considered particularly important. All United States applicants to graduate-degree programs in electrical engineering are requested to take the Graduate Record Examination, described in Section 3.

Every regular graduate student in electrical engineering is required to complete a written examination during his first year of graduate study. This examination is designed to explore the student's undergraduate preparation in his principal areas of interest; it is intended primarily to help the student evaluate his preparation and to help the faculty counseling him with respect to his graduate program. Special examinations will be arranged for those for whom the regular examination is inappropriate. A detailed description of the current examination and procedures will be sent to each applicant after he has been accepted for admission.

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 take a few classroom subjects, usually two or three each term, in addition to their research or teaching. The subjects are wholly elective and are not restricted to those given by the Department of Electrical Engineering; however, the program of study must be well balanced, emphasizing one or more of the theoretical or experimental aspects of electrical engineering. A research thesis is required.

All of the four undergraduate programs, previously described, 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.

ENGINEER DEGREE

Able students who desire more extensive training than is possible within the Master's degree program are encouraged to study for the Electrical

Engineer degree. The course of studies for this degree is elective, and a thesis is required. The program ordinarily requires at least four terms of graduate study beyond the Bachelor's degree level.

The general requirements for the Engineer degrees are given in Section 3.

DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY

The general requirements for the Doctor's degree are given in Section 3.

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. Doctoral candidates are expected to perform thesis research which is a significant contribution to knowledge, and to participate in the educational program of the Department. Students entering on graduate work in the Department without significant research experience are usually required to qualify first for the Master's or Electrical Engineer degree; the quality of the thesis submitted for these degrees is a major component in the decision to admit a student to the doctoral program. For most students the written examination required of all electrical engineering graduate students during their first graduate year is acceptable as the written part of the General Examination.

Each applicant for the doctorate in electrical engineering is required to satisfy the language requirements as stated in Section 3 of this Catalogue. Modern languages should be selected from German, Russian, and French.

A Minor is required by the Department, and must have departmental approval.

Department of Mechanical Engineering

ASCHER HERMAN SHAPIRO, SC.D.
Ford Professor of Engineering; Head of the Department

WILLIAM MacGREGOR MURRAY, SC.D.
Professor of Mechanical Engineering; Executive Officer

ALI SUPHI ARGON, SC.D.
Professor of Mechanical Engineering

STANLEY BACKER, SC.D. *(Absent)*
Professor of Mechanical Engineering

NATHAN HENRY COOK, SC.D. *(Absent)*
Professor of Mechanical Engineering

STEPHEN HARRY CRANDALL, PH.D.
Professor of Mechanical Engineering

JACOB PIETER DEN HARTOG, PH.D., D.ENG., D.APPL.SC., D.TECH.SC.
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JAMES ALAN FAY, PH.D.
Professor of Mechanical Engineering

PETER GRIFFITH, SC.D.
Professor of Mechanical Engineering

JAMES COLLYER KECK, PH.D.
Ford Professor of Engineering

JOSEPH HENRY KEENAN, LL.D.
Professor of Mechanical Engineering, Emeritus; Senior Lecturer

SHIH-YING LEE, SC.D.
Professor of Mechanical Engineering

PATRICK LEEHEY, PH.D.
Professor of Naval Architecture

ROBERT WELLESLEY MANN, SC.D.
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FRANK AMBROSE McCLINTOCK, PH.D. *(Absent)*
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Professor of Mechanical Engineering

ERNEST RABINOWICZ, PH.D.
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HERBERT HEATH RICHARDSON, SC.D.
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BRANDON GARNER RIGHTMIRE, SC.D.
Professor of Mechanical Engineering

AUGUSTUS RUDOLPH ROGOWSKI, S.M.
Professor of Mechanical Engineering

WARREN MAX ROHSENOW, D.ENG.
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TAU-YI TOONG, SC.D.
Professor of Mechanical Engineering

KENNETH ROBERT WADLEIGH, SC.D.
Professor of Mechanical Engineering; Dean of Student Affairs

HERBERT HORACE WOODSON, SC.D.
Philip Sporn Professor of Energy Processing

DOUGLAS PAYNE ADAMS, S.B., A.M.
Associate Professor of Mechanical Engineering

JOHN PATRICK APPLETON, PH.D.
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DWIGHT MAYLON BILLY BAUMANN, SC.D.
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CHARLES ADOLPH BERG, SC.D.
Associate Professor of Mechanical Engineering

ARTHUR EDWARD BERGLES, PH.D.
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FORBES TAYLOR BROWN, SC.D.
Associate Professor of Mechanical Engineering

STEVEN ANSON COONS
Associate Professor of Mechanical Engineering

CLARENCE FORBES DEWEY, PH.D.
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WILLIAM RUSSELL FERRELL, PH.D.
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SUZUE ISHII, D.E.
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DEANE LENT, A.B.
Associate Professor of Mechanical Engineering

ALLAN DALE PIERCE, PH.D.
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THOMAS BROWN SHERIDAN, SC.D.
Associate Professor of Mechanical Engineering

JOSEPH LECONTE SMITH, JR., SC.D.
Associate Professor of Mechanical Engineering

PRESCOTT ARTHUR SMITH, S.B.
Associate Professor of Mechanical Engineering; Assistant Secretary of the Faculty

AIN ANTS SONIN, PH.D.
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ROBERT ERWIN STICKNEY, PH.D.
Associate Professor of Mechanical Engineering

DAVID GORDON WILSON, PH.D.
Associate Professor of Mechanical Engineering

Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

ERNEST GEORGE CRAVALHO, PH.D.
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MICHEL YVES JAFFRIN, PH.D.
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IGOR PAUL, SC.D.
Assistant Professor of Mechanical Engineering

RONALD CARL ROSENBERG, PH.D.
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RICHARD FRANK SALANT, SC.D.
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DAVID NEAL WORMLEY, PH.D.
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IOANNIS VASSILIOU YANNAS, PH.D.
du Pont Assistant Professor of Mechanical Engineering

Administrative Officer

JAMES HARRISON EAGER, S.M.

Senior Lecturer

GEORGE NICHOLAS HATSOPOULOS, SC.D.

Lecturers

MICHAEL SAMPSON BARAM, B.S., LL.B.
PHILIP ALDRICH DRINKER, PH.D.
RICHARD PAINE PARMELEE, PH.D.

Instructors

ROSSER B. MELTON, JR., S.M.
ROBERT CHARLES SHELDON, M.E.
RICHARD STEVENSON SIDELL, S.B.
WILLIAM LAWRENCE VERPLANK, S.M.

Technical Instructors

FREDERICK HAROLD ANDERSON
RALPH JOHN BOWLEY
CLARENCE WILLIAM CHRISTIANSEN
JOHN LEACH

Senior Research Associate

EMERY IMRE VALKO, PH.D.

Research Associates

HUW GRIFFITH DAVIES, PH.D.
MARCEL PAUL ESCUDIER, PH.D.
THOMAS IAN McLAREN, PH.D.
VENKATARAMAIAH SREEDHARA MURTHY, PH.D.

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Professor of Mechanical Engineering, Emeritus

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CARL LOUIS SVENSON, S.M.
Professor of Mechanical Engineering, Emeritus

CHARLES FAYETTE TAYLOR, PH.B., M.E.
Professor of Automotive Engineering, Emeritus

GORDON BALL WILKES, S.B.
Professor of Heat Engineering, Emeritus

MECHANICAL ENGINEERING

As perhaps the broadest in scope of all the engineering fields, mechanical engineering is not identified with nor restricted to a particular technology, a particular vehicle, a particular device, nor a particular system. It is in fact concerned with so many areas of modern technology that the tasks of the mechanical engineer are most interesting and varied.

We live in an era when technology is changing so rapidly that the education of an engineer must prepare him with a sound base for working in fields which perhaps do not even exist at the time he gets his degree. The greatest strength of the undergraduate curriculum in mechanical engineering, which combines a broad scientific training with project-oriented work in the laboratory and in design, is that it is ideally suited to the education of an engineer for the times in which we live.

How broad is the scope of mechanical engineering can best be exemplified by listing some of the areas in which active research is proceeding in the Department of Mechanical Engineering at the forefront of one or another technology. These research areas are listed within the three main divisions into which the Department is organized.

1. *Mechanics and Materials*
Continuum mechanics: elasticity, plasticity, rheology
Physics and mechanics of deformation and fracture in materials
Dynamics, vibrations, acoustics
Surface physics, wear, lubrication, friction
Manufacturing processes, machines, materials and systems
Fibers, polymers, textiles

2. *Thermal and Fluid Sciences*
Thermodynamics, kinetic theory, statistical mechanics
Heat transfer, mass transfer
Gas-surface interactions
Fluid mechanics, plasma dynamics
Combustion
Cryogenics
Power generation and transmission
Biofluid mechanics
Air pollution

3. *Systems and Design*
Modeling, analysis, synthesis and management of systems
Control system theory and design
Man-machine systems
Instrumentation and measurement systems
Electromechanics
Sensory aids and prostheses
Societal systems design: transportation, underdeveloped technologies, urban problems
Fluidics and fluid power control
Computer-aided engineering: computer graphics, information storage and retrieval
Power and propulsion systems

There can be only one firm foundation for a career as diverse and challenging as that faced by the mechanical engineer. Starting with mathematics, physics and chemistry, he must acquire some mastery in the engineering sciences: dynamics, materials, fluid dynamics, heat and mass transport, thermodynamics and statistical mechanics, systems analysis, and controls. With this he must experience the ways in which scientific knowledge can be put to use in the development and design of useful devices and processes. This is the art of engineering. To teach this art, largely by project-oriented work of creative nature, is the primary object of subjects in laboratory and 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.

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, chemistry, and the basic engineering sciences. 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 several basic programs, some centered around engineering design and applications and others centered around engineering science. The Course leads either to the degree of Bachelor of Science in Mechanical Engineering or to the degree of Bachelor of Science. The objectives and requirements for these two degrees are described subsequently.

Those students who enter the Department at the end of the first year will generally have 24 units of free elective in the second year, and

about 40 units of free elective in the two upper years. A student may use this freedom in many different ways. He may, for example, elect additional upperclass subjects in the humanities and social sciences. He may take a substantial minor program in industrial management. He may elect advanced subjects in physics, mathematics, and mechanical engineering, to prepare for future graduate work. He may arrange his electives so that, as early as possible, he can focus on professional subjects — in some relatively specific area, such as automatic control. Or he may explore allied fields — for instance, biology, if he is interested in biomedical engineering.

Some students may wish to defer entering the Department until the end of the second year. Assuming that they have a satisfactory academic record and have averaged 45 units per term, they can expect to graduate in the normal four-year period provided that they have met the General Institute Requirements in Chemistry, Mathematics, and Physics, and have also taken DIFFERENTIAL EQUATIONS (18.034).

In any case, each student is urged to consult with his Faculty Counselor as soon as he has decided to enter the Department.

In order to encourage cross-fertilization of disciplines, substitution of subjects of similar content for those specified below may be permitted by petition to the Department. Also, to foster substantial research and design achievement, the Department permits up to 6 units of additional thesis credit, subject to approval of the student's Faculty Counselor.

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.

ENGINEERING

Building on a base of the pure sciences and the engineering sciences, a student interested in engineering applications may use his elective opportunities to concentrate in a coherent set of subjects in a 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. Such areas include the following:

Power and Propulsion. Power production pervades modern technology: electricity for home and industry; propulsion of ships and aircraft by propellers and jet engine drives; rocket propulsion; auxiliary power and propulsion requirements of orbiting and interplanetary vehicles. The variety of devices has increased tremendously in the past decade. Internal combustion engines and steam power plants have been joined by gas turbines, jet engines, and rockets as well-established members of the hierarchy, while nuclear power, magnetohydrodynamic power generation, thermionic and thermoelectric power, magnetohydrodynamic and electric thrust engines, and fusion power from hydrogen plasmas are now exciting areas of current development.

The subjects available for power and propulsion programs give each student experience in the scientific approach to 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, magnetohydrodynamics and plasma dynamics, and design — and applied to the analysis and design of engines, power plants, and exotic power supplies.

Design, Manufacturing, and Controls. Design, manufacturing, and automatic control 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.

In our rapidly evolving era of automation and automatically controlled systems and processes, many challenging technical problems lie ahead for the engineer. These span the range from the physics of failure and the engineering of reliability for space vehicle control systems to the controlled optimization of large complexes for

the supply of water and power, for the transportation of people and materials, and for the production of fabricated goods and processed chemicals. Moreover, the concepts of active systems and feedback control not only promote effective use of physical hardware but also contribute toward deeper understanding of the interactions between the human being and his mechanized world. The mechanical engineering program offers a variety of core and elective subjects and many opportunities for original research which serve these interests.

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 Department of Mechanical Engineering.

A program in industrial design can be arranged.

ENGINEERING SCIENCE

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.

A student interested in engineering science may use his elective opportunities in more advanced 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.

Experience in research is an essential part of any 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.

THE DEGREE: BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

The faculty of the Department has formulated a balanced and coherent program for those students who desire a broad background in subjects and methods underlying the field of mechanical engineering. The curriculum requirements for this degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)					
	Specific science and humanities and social science subjects				**128**
	The subjects 2.01, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	The subjects 2.672 and 2.673, which are required in the Departmental Program, appear on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects				
2.01	MECHANICS OF SOLIDS	4	0	8	
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8	
2.03	DYNAMICS	3	0	6	
2.201	FLUID MECHANICS	4	0	8	
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
2.42	ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS	4	0	8	
2.60	APPLIED THERMODYNAMICS	3	0	6	
2.672	EXPERIMENTAL ENGINEERING I	1	3	2	
2.673	EXPERIMENTAL ENGINEERING II	0	4	2	
2.731	ENGINEERING DESIGN	3	3	6	
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4	
8.03T	PHYSICS III	5	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	THESIS			9	
					144
	Restricted Electives				
3.13	MATERIALS SCIENCE I				
	or	4	3	5	
3.141	SCIENCE OF MATERIALS				
					12
	Unrestricted Electives[1]				**76**
Total units required for the S.B. degree					**360**

[1] Schedules of students in Course II may always be arranged to leave available 24 units of unrestricted elective in the second year. The Department recommends 8.04 and at least one subject in electrical engineering or electrical science as elective subjects.

Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

THE DEGREE: BACHELOR OF SCIENCE

Many students have a defined goal which can best be met by organizing a curriculum specifically tailored to that goal. Such a curriculum may be significantly different from that required for the degree of Bachelor of Science in Mechanical Engineering or, for that matter, different from that required for a degree in any specified field at M.I.T. For instance, some students may wish to have a substantial component of biology and physiology in their programs, to prepare for biomedical engineering. Others may wish to combine knowledge of solids with knowledge of electrical circuits and devices, or knowledge of fluids with knowledge of physical chemistry and reaction kinetics.

To meet such needs, the Department offers the degree of Bachelor of Science, with a significant part of the curriculum made up of "planned electives." These are to be chosen by agreement between the student and a departmental officer in such a manner that the complete curriculum is coherent and in pursuit of a clear objective.

Students who wish to study for this degree must so advise the Department by the beginning of the junior year in order that there be adequate opportunity for planning the complete curriculum.

The curriculum requirements for this degree are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)					
	Specific science and humanities and social science subjects.				**128**
	The subjects 2.01, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirements				**12**
	The subjects 2.672 and 2.673, which are among the restricted electives, appear on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.				
DEPARTMENTAL PROGRAM					
	Required Subjects				
2.01	MECHANICS OF SOLIDS	4	0	8	
8.03T	PHYSICS III	5	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	THESIS		9		
					45
	Restricted Electives				
	Five of the following subjects:				
3.141	SCIENCE OF MATERIALS				
	or	4	3	5	
3.13	MATERIALS SCIENCE I				
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8	
2.03	DYNAMICS	3	0	6	
2.201	FLUID MECHANICS	4	0	8	
2.30	MECHANICAL BEHAVIOR OF MATERIALS	3	2	4	
2.403	THERMODYNAMICS				
	or	4	0	8	
2.42	ELEMENTS OF CLASSICAL AND STATISTICAL THERMODYNAMICS				
2.60	APPLIED THERMODYNAMICS	3	0	6	
2.672	EXPERIMENTAL ENGINEERING I	1	3	2	
2.673	EXPERIMENTAL ENGINEERING II	0	4	2	
2.731	ENGINEERING DESIGN	3	3	6	
2.861	ENGINEERING DESIGN AND MANUFACTURE	4	4	4	
					at least **54**
	Planned Electives				
	A coherent selection of at least five subjects which, together with the remaining portions of the student's program, is aimed at a well-defined educational goal. The planned electives are to be agreed upon between the student and a designated Faculty Counselor of the Department of Mechanical Engineering.				at least **57**
	Unrestricted Electives[1]				up to **64**
Total units required for the S.B. degree					**360**

[1] Schedules of students may always be arranged to leave available 12 units of unrestricted elective in the second year.

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 of 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, but only a single thesis 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 provides 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 the following required plant work in place of 8 units of elective:

2.951	INDUSTRIAL PRACTICE	40 h.p.w.
2.952	INDUSTRIAL PRACTICE	0 8 0

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 or Doctor of Philosophy.

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. The Department requirements for admission are not specific, since a capable student with a more general preparation has the opportunity to establish his background in mechanical engineering by taking the most advanced undergraduate subjects which his abilities and preparation will permit.

The fields of advanced study and research are those briefly listed on page 135. Well-equipped facilities are available in the following laboratories:

Acoustics and Vibrations Laboratory

Atomic and Molecular Kinetics Laboratory
Automotive Laboratory, Sloan
Combustion and Propulsion Laboratory
Computer
Cryogenic Engineering Laboratory
Energy Conversion Laboratory
Engineering Projects Laboratory
Environmental Control Laboratory
Fibers and Polymers Laboratory
Fluid Mechanics Laboratory
Fluid Power Control Laboratory
Gas Turbine Laboratory
Heat Transfer Laboratory
Man-Machine Systems Laboratory
Materials Laboratory
Materials Processing Laboratory
Power Systems Engineering Laboratory
Sensory Aids Center
Stress Analysis Laboratory
Surface Laboratory
Vacuum Laboratory

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 Department of Mechanical Engineering. 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 advisor. The program should be well balanced, emphasizing one or more of the analytical, economic, design, or experimental aspects of the field.

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 at least two years to fulfill 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 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 Department of Mechanical Engineering 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 OR DOCTOR OF PHILOSOPHY

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 Program of Advanced Study, a Minor program, a thesis in the field of Mechanical Engineering or in the field of Materials Engineering, and the language requirement specified for the doctorates on page 81 of the Institute degree requirements.

The program of advanced study and research may be selected in any field of science or engineering approved by the Department Committee on Graduate Studies. While no fixed number of units is prescribed, the usual program includes a substantial number of 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.

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 Program of Advanced Study 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 based on research in the field of fibrous materials.

Engineering

DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

Department of Metallurgy and Materials Science

THOMAS BURNESS KING, PH.D.
Professor of Metallurgy; Head of the Department
CLYDE MELVIN ADAMS, JR., SC.D. (*Absent*)
Abex Corporation Professor of Metallurgy
BENJAMIN LEWIS AVERBACH, SC.D.
Professor of Metallurgy
WALTER ALAN BACKOFEN, SC.D. (*Absent*)
Professor of Metallurgy
MICHAEL BERLINER BEVER, DR. IUR., SC.D.
Professor of Metallurgy
JOHN WERNER CAHN, PH.D.
Professor of Metallurgy
MORRIS COHEN, SC.D.
Ford Professor of Materials Science and Engineering
PHILIP LOUIS DE BRUYN, SC.D.
Professor of Metallurgy
JOHN FRANK ELLIOTT, SC.D.
Professor of Metallurgy
CARL FREDERICK FLOE, SC.D.
Professor of Metallurgy; Vice President, Research Administration
HARRY CONSTANTINE GATOS, PH.D.
Professor of Electronic Materials; Associate Director of the Center for Materials Science and Engineering
ANTOINE MARC GAUDIN, SC.D.
Richards Professor of Mineral Engineering, Emeritus; Senior Lecturer
NICHOLAS JOHN GRANT, SC.D.
Professor of Metallurgy
WILLIAM DAVID KINGERY, SC.D.
Professor of Ceramics
ROBERT EDWARD OGILVIE, SC.D.
Professor of Metallurgy
CYRIL STANLEY SMITH, SC.D.
Institute Professor; Professor of Metallurgy
HERBERT HENRY UHLIG, PH.D.
Professor of Metallurgy
JOHN WULFF, D.SC.
Professor of Metallurgy, Emeritus; Senior Lecturer
JOHN FRANK BREEDIS, D.ENG.
Associate Professor of Metallurgy
ROBERT LOUIS COBLE, SC.D. (*Absent*)
Associate Professor of Ceramics
MERTON CORSON FLEMINGS, SC.D.
Associate Professor of Metallurgy
ROY KAPLOW, SC.D.
Associate Professor of Metallurgy
SIMON CHARLES MOSS, SC.D. (*Absent*)
Associate Professor of Metallurgy
ROBERT MICHAEL ROSE, SC.D.
Associate Professor of Metallurgy
AUGUST FERDINAND WITT, PH.D.
Associate Professor of Metallurgy
THOMAS OWENS ZIEBOLD, PH.D.
Associate Professor of Nuclear Materials
DAVID LEWIS HOLT, SC.D.
Assistant Professor of Metallurgy
KEITH HUBER JOHNSON, PH.D.
Assistant Professor of Metallurgy
CYRIL JOSEPH MOGAB, SC.D.
Assistant Professor of Ceramics
BARRY HAROLD ROSOF, S.M.
Assistant Professor of Metallurgy
KENNETH CALVIN RUSSELL, PH.D.
Assistant Professor of Metallurgy
DAVID JULIAN SELLMYER, PH.D.
Assistant Professor of Metallurgy
DONALD ROBERT UHLMANN, PH.D.
Assistant Professor of Ceramics
BERNHARDT JOHN WUENSCH, PH.D.
Assistant Professor of Ceramics

Administrative Officer

DOUGLAS CRAIG JOHNSTON, S.M.

Technical Instructors

ARTHUR JEREMIAH GREGOR
PAUL FREDERICK HUGHES

Research Associates

JOHN WASHBURN BRACKETT, PH.D.
BILL CORMANN GIESSEN, SC.D.
THEODOULOS ZENONOS KATTAMIS, SC.D.
MARC ONILLON, DR.SC.PHY.

Professors Emeriti

JOHN CHIPMAN, PH.D., SC.D.
Professor of Metallurgy, Emeritus
ANTOINE MARC GAUDIN, SC.D.
Richards Professor of Mineral Engineering, Emeritus; Senior Lecturer
VICTOR OLIVER HOMERBERG, SC.D.
Professor of Physical Metallurgy, Emeritus
FREDERICK HARWOOD NORTON, SC.D.
Professor of Ceramics, Emeritus
JOHN TORREY NORTON, SC.D.
Professor of the Physics of Metals, Emeritus
JOHN WULFF, D.SC.
Professor of Metallurgy, Emeritus; Senior Lecturer

METALLURGY AND MATERIALS SCIENCE

The Department of Metallurgy and Materials Science is concerned with the principal engineering materials upon which modern civilization depends. These are the skeleton, or even the whole substance, of structures, machines and equipment, and mechanical and electrical devices. Modern society cannot satisfy its needs for materials from wood, cement, and crude metals alone. The mechanical, chemical, thermal, and electrical properties demanded of materials today require much greater sophistication in the selection, treatment, and assembly of a bewildering variety of substances designed for specific needs.

Fortunately, there is a key to the rational use and development of materials, simple or complex, which is the basic contribution of the metallurgist. It is an understanding of the relations between structure and properties and, equally important, the knowledge of how structure may be controlled to influence properties. Structure has many levels: atomic, electronic, crystal, and gross. Even the lack of crystalline structure, as in glasses and some polymers, the blending of gross structures, as in composites, and defects in crystalline structures, as in electronic materials, are important features in the development of properties.

The name of the Department has both historical and technical significance. There is more to metallurgy and materials science than structural chemistry and solid-state physics. The metallurgist is also an engineer who must prepare materials of very high purity and know how to blend or alloy them, how to change their structure by heat treatment, deformation, phase change, and joining. He must, in effect, design materials with the desired combinations of properties; this is one of the applied aspects of his work. Historically, the metallurgist takes his name from the oldest, most abundant, and most serviceable of all engineering materials. But today he must know the place of other materials, such as ceramics, plastics, and other nonmetallics, in the scheme of things. The same methods which have been so vital in the development of an extraordinary array of metals and alloys have been just as fruitful in the evolution of improved ceramics, plastics, and electronic materials.

Metallurgists and materials engineers must bring together many skills in coping with actual materials problems. Some specialize in the preparation of materials, for which a basic knowledge of chemistry and control systems is most helpful. Others are concerned with the elucidation of structure-property relations, for which a background in solid-state science is more useful. Still others deal with the manipulation of shape and properties, for which an understanding of the mechanics of materials is critical. The versatile man can apply his basic knowledge to any of these areas, whether in research, development, production, or management.

Because the field of materials is so broad, the Department has chosen to concentrate its activities in metals, ceramics, and electronic materials, though it should be emphasized that the appropriate knowledge and methods can be applied successfully to the technology of any material.

Metallurgy and materials science are of vital importance to modern industry. The design and operation of propulsion units such as gas turbines and rocket motors, of energy producers such as nuclear reactors, or energy converters such as magnetohydrodynamic and thermoelectric generators, and of electrical and mechanical devices are critically dependent on the availability of materials with the requisite blend of properties. Men with skills to design these materials are in great demand by industry and government. They find challenging opportunities in a large variety of positions in operations, development and research in the basic materials-producing industries, chemical and metallurgical, in the consumer industries, which make products ranging from automobiles to surgical instruments, and in the space and defense oriented industries.

THE UNDERGRADUATE PROGRAM

Metallurgy and Materials Science (Course III)

The undergraduate program caters to the diverse needs of students who aim for a terminal degree and those who intend to pursue graduate work, to those who are more inclined toward engineering application as well as those who prefer solid-state science. The decision to concentrate on the physics, chemistry, or engineering of materials may be reached by students as late as the sophomore year or even during the junior year.

For these reasons, the curriculum is flexible. Understanding of materials is developed from a foundation of physical and engineering science, a core of subjects in mechanics, thermodynamics, crystal structure, and structure-property relations. These essential subjects are taught within the Department, so that meaningful examples can be used to illustrate the material. However,

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DEPARTMENT OF METALLURGY AND MATERIALS SCIENCE

appropriate substitutions of subjects taken in other departments are permitted.

The elective program, constituting more than 20 per cent of the student's time, is chosen, with the help of an advisor, to give depth in one or more technical areas such as the preparation and purification of materials, including the chemical process technology employed by steelmakers; the processing and fabrication of materials by deformation, heat treatment, and phase change; the study and control of structure-property relations in metallic and ceramic materials; and the physics of solid materials generally. Many graduate subjects are open to undergraduates having the necessary preparation.

Other choices under the elective program are, of course, possible. A student may focus his elective time on modern production or research management techniques in the materials industry, or he may simply prepare for later graduate study.

Participation in laboratory work by undergraduates is an integral part of both engineering and research experience. Some laboratories are associated with particular subjects, but, especially in thesis work, the undergraduate has access to the extensive facilities for graduate research in materials described in a later section.

The teaching facilities, some of which are located in the Center for Materials Science and Engineering, include an electron-optics laboratory with X-ray and electron diffraction equipment; electron microscopes and microanalyzers; laboratories for microscopic studies, heat treatment, and physical testing of materials; and complete test apparatus for the study of mechanical, thermal, electrical, and magnetic properties. In the ceramics laboratories most types of refractory as well as electrical ceramics and glasses can be prepared or their properties studied. Facilities for the growth and characterization of metallic and non-metallic crystals are available in several laboratories. The chemical metallurgy laboratories contain equipment for the study of heat and mass flow and for thermodynamic and kinetic investigations at high temperatures. The materials processing laboratories are equipped for work on deformation, solidification, joining, and vapor deposition as processing techniques. Laboratories in surface chemistry, corrosion, and mineral processing are also open to undergraduates. Other services include a complete analytical laboratory and computation facilities with remote consoles.

The Course leads to the degree of Bachelor of Science in Metallurgy and Materials Science. The curriculum requirements for the degree are given below:

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 99*)					
	Specific science and humanities and social science subjects.				**128**
	ECONOMIC PRINCIPLES I (14.01) is recommended in the upperclass humanities and social science program.				
	The subjects 3.00, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement (see page 49).				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
3.00	THERMODYNAMICS OF MATERIALS	4	0	8	
3.01T	THERMODYNAMICS AND STATISTICAL MECHANICS	3	0	9	
3.02	CHEMISTRY OF MATERIALS	3	3	6	
3.11	MECHANICS OF MATERIALS	4	0	8	
3.12	PRINCIPLES OF CRYSTALLOGRAPHY AND X-RAY DIFFRACTION	4	3	5	
3.13	MATERIALS SCIENCE I	4	3	5	
3.15	MATERIALS SCIENCE II	4	3	5	
8.03T	PHYSICS III	5	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
	[3]THESIS		12		
					120
	Restricted Electives				**20** to **24**
	Physical Metallurgy *One of the following subjects:*				
3.14	PHYSICAL METALLURGY I	4	3	5	
3.144	PHYSICAL METALLURGY I	4	0	4	
	Materials Processing *One of the following subjects:*				
3.18	MATERIALS PROCESSING	4	3	5	
3.188	MATERIALS PROCESSING	4	0	4	
	Unrestricted Electives[2]				**80** to **76**
Total units required for the S.B. degree					**360**

[1] Substitution of subjects of similar content is permitted in some cases.

[2] Schedules of students in Course III may always be arranged to leave available 12 units of unrestricted elective in the second year.

[3] Up to 6 additional units of thesis may be used as elective.

Students who decide during the first year at M.I.T. to study Metallurgy and Materials Science can facilitate their later progress by ensuring that their second-year subjects include additional mathematics and physics as well as 3.00 and 3.11, or their equivalents. The third and fourth years may then be devoted to study, in some depth and with adequate preparation, of areas such as physical metallurgy, the physics of solids, chemical metallurgy, or ceramics, through appropriate use of upperclass elective time.

Some students, on the other hand, do not wish to make a Course choice until the junior year or

may wish to use their elective time to the fullest possible extent in the second year rather than in later years. Generally, it will still be possible to complete the Departmental Program and Institute Requirements in two more years, especially if one of the second-year Science Distribution Subjects is in thermodynamics or mechanics of solids; but elective freedom, particularly in the fourth year, will have been sacrificed. An inadequate preparation in physics will cause the most difficulty, though a schedule may still be arranged.

GRADUATE STUDY IN METALLURGY, MINERAL ENGINEERING, CERAMICS, AND MATERIALS SCIENCE

The Department conducts a large and active fundamental research program on the structure and properties, preparation, and processing of materials, with emphasis on metals and ceramics. Graduate research is an important part of the educational process, and interaction between graduate and undergraduate is encouraged through participation in research. Students are allowed to choose research projects for which they have enthusiasm and generally work with an individual faculty advisor. Most research projects result in significant findings which are published in the scientific literature. Graduate subjects of instruction, in this and other departments, allow the student to pursue areas in depth but also afford the opportunity for a broad view of the field of metals and materials. Though there are many individual research laboratories in the Department, there is much interaction and sharing of experimental facilities between them. Such interaction extends to laboratories of other departments, and joint projects are common. Interdisciplinary research is facilitated by the Center for Materials Science and Engineering, of which metallurgy is an important part.

STRUCTURE AND PROPERTIES OF MATERIALS

The detailed structure of materials may be related to their mechanical, thermal, optical, and electrical properties. The study of such relationships with mechanical properties is one of the principal concerns of the physical metallurgy laboratories. The methods of electron and X-ray diffraction and electron microscopy are used to examine microstructural lattice imperfections induced by plastic flow and phase transformations; a classic example is the investigation of strengthening mechanisms in steel. Thermodynamic techniques also contribute to such research and are extended to investigation of deformation and annealing of metals. The mechanism of flow and fracture at high temperatures is studied in the high-temperature metals laboratory which is also concerned with the properties of metal, metal-oxide alloys. Deformation and fracture characteristics of ceramics, including even ice, are investigated in the ceramics laboratories. The mechanical properties of anisotropic and composite materials are also of interest from the structural viewpoint. Dislocation interactions in materials at low temperatures can be studied by the modern techniques available. An electron optics group is concerned with developing new tools such as micro-X-ray diffraction and the application of the electron microprobe to produce Kossel line patterns. Kinetic processes are not neglected; for example, there is important research on stress relief, recrystallization, flow and fracture and diffusion under stress.

Work on electrical properties proceeds in various laboratories. The superconductivity of metals, alloys, compounds, and composites and the relationship of defect microstructures to superconducting properties are extensively studied. The surface characteristics of semiconductor compounds and the study of materials for thermionic emission are part of the research on electronic materials. Thermal, optical, and electrical properties of both crystalline and noncrystalline ceramic materials form one of the principal areas of research in ceramics. The effects of irradiation damage on spontaneous magnetization and the study of spin disorder in magnetic alloys are examples of work on magnetic properties.

Work on Fermi surfaces and fine X-ray structure studies are conducted by a group in the physics of solids.

PREPARATION OF MATERIALS

Much of the research in this area is concerned with establishing thermodynamic properties and studying the mechanism of interaction between substances. In the chemical metallurgy laboratories, studies are made of the thermodynamic properties of liquid and solid metals and alloys, utilizing such methods as high-temperature solution calorimetry, reversible electrochemical cells, measurement of vapor pressures, and equilibration between gases and condensed phases. There are also studies of diffusion in liquid alloys and salts, on the kinetics of reactions between gases

and liquid metals, and of electrode kinetics in high-temperature systems.

Separation of materials is an important part of preparation, and in the mineral engineering laboratories there are studies of the mechanism of flocculation of wet solids, of the fragmentation of materials, and of surface chemistry, including contact angle hysteresis, the electrochemistry of solid-liquid interfaces, and the kinetics of leaching processes.

The reaction of materials with their environments extends to fundamental corrosion research, including the measurement of contact potentials and studies of polarization, passivity, the nature of surface films, and the mechanisms of oxidation and corrosion under stress.

Other laboratories, for example ceramics and materials processing, require specific materials prepared by powder methods, vacuum melting and deposition, and zone refining.

PROCESSING OF MATERIALS

The processing of materials to influence shape and properties involves study of the fundamental processes of solidification, deposition, deformation, and joining.

Research on solidification is conducted on aqueous solutions, gas hydrates, metals, and alloys. The detailed structures produced by directional and slow solidification, as in castings, and by rapid solidification, as in arc-deposition, are of particular interest. Deposition of materials from the vapor state and plasma spraying are also studied.

Research on deformation processing involves the fundamentals of flow, fracture, and fatigue as well as studies of friction and lubrication during deformation, plastic instability, and superplasticity.

Work on joining includes fundamental studies of heat flow and material properties in arc, electron-beam, and laser welding, of vapor processing and surface treatment, and of sintering and brazing.

EQUIPMENT

The latest research equipment is available for studies in all of these areas. Facilities include all types of high-temperature furnaces in chemical metallurgy and ceramics, vacuum induction and vacuum arc-melting furnaces, electron beam melting apparatus, and zone refining and crystal growing equipment in materials processing. In physical metallurgy and electron optics, the latest electron microscopes, electron diffraction apparatus, equipment for metallographic examination, X-ray diffraction apparatus for structural analysis and fine-structure studies, X-ray fluorescent analyzers, and electron probe microanalyzers are all available, in addition to specialized equipment. Equipment for testing mechanical properties at high and low temperatures under a variety of strain rates is available in physical metallurgy and materials processing. Materials can be deformed in many ways, and the heavier equipment includes rolling and forging apparatus. A completely equipped laboratory is available for fundamental solidification studies. The welding laboratory includes welding, plasma-arc melting, electron-beam, and laser apparatus. All the necessary equipment for electrochemical studies in the corrosion laboratory and counting equipment for tracer studies in mineral engineering are available.

More recent additions include ultra-high vacuum equipment, extensive metallic and semiconductor crystal-growing apparatus, equipment for Fermi surface studies, and a high-pressure laboratory.

The Department maintains an analytical laboratory, machine and instrument-making shops, a student machine shop, and remote computation consoles.

Requirements for Graduate Study

The general admission requirements are those given in Section 3 of this Catalogue. Students whose undergraduate preparation is in metallurgy will generally be familiar with the principles of heat and fluid flow, thermodynamics, and materials science, with the emphasis on metallurgy. Those whose undergraduate preparation is in other branches of science and engineering and who wish to enroll for advanced degrees in the Department may find it advantageous to take some undergraduate subjects during their first year of graduate study.

It is expected that those who do graduate work in metallurgy will have studied the following subjects or their equivalents:

THERMODYNAMICS AND STATISTICAL MECHANICS (3.01)
MATERIALS SCIENCE I (3.13)

Graduate students whose preparation does not include the above subjects, or their equivalents, are expected to complete them in the early part of their graduate work.

Students who wish to do graduate study in ceramics generally have varied backgrounds, and there are no special requirements. However, all entering graduate students are required

to register for CERAMICS (3.06) unless they have had similar training elsewhere.

For students in materials science, the general Institute requirements for admission, given in Section 3 of this Catalogue, are sufficient. Programs are arranged on an individual basis depending on the preparation and interests of the student. Students who have not taken the following subjects or their equivalents are expected to complete them as early as possible.

THERMODYNAMICS AND STATISTICAL MECHANICS (3.01)
MATERIALS SCIENCE I (3.13)

The Graduate Degrees

The Department offers the following graduate degrees: Master of Science in Metallurgy; Master of Science in Ceramics; Metallurgical Engineer; Mineral Engineer; Doctor of Science or Doctor of Philosophy.

The graduate degree requirements are as set forth in Section 3 of this Catalogue. The Department requires that candidates for the doctoral degrees pass a qualifying examination before proceeding with their programs of study and research and satisfy a Minor requirement. Information on this examination and on the areas covered by the general examination is available from the Chairman of the Departmental Committee on Graduate Students.

Assistantships and Fellowships

The Department offers assistantships and fellowships for graduate study. Research and teaching assistantships are available in all of the fields in which the Department is active. Further information may be obtained from the Chairman of the Departmental Committee on Graduate Students.

Department of Naval Architecture and Marine Engineering

ALFRED ADOLF HEINRICH KEIL, DR. RER. NAT.
Professor of Naval Architecture; Head of the Department
MARTIN AARON ABKOWITZ, PH.D.
Professor of Naval Architecture
JACOB PIETER DEN HARTOG, PH.D., D.ENG., D.APPL.SC., D.TECH.SC.
Professor of Mechanical Engineering, Emeritus; Senior Lecturer
JOHN HARVEY EVANS, B.ENG.
Professor of Naval Architecture
ERNST GABRIEL FRANKEL, MAR.MECH.E.
Professor of Marine Engineering
DEAN ALDEN HORN, S.M.
Captain, U. S. Navy;
Professor of Naval Construction
JUSTIN ELLIOT KERWIN, PH.D.
Professor of Naval Architecture
PATRICK LEEHEY, PH.D.
Professor of Naval Architecture
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus; Senior Lecturer
PHILIP MANDEL, B.S.
Professor of Naval Architecture
NORMAN JUDSON PADELFORD, PH.D., LL.D.
Professor of Political Science
KOICHI MASUBUCHI, D.ENG.
Associate Professor of Naval Architecture
JOHN NICHOLAS NEWMAN, SC.D.
Associate Professor of Naval Architecture
SHANNON CURTIS POWELL, DOTT.ING.
Associate Professor of Marine Engineering
SHERMAN CLARK REED, NAV.E.
Commander, U. S. Navy
Associate Professor of Naval Engineering
DAMON ELLIS CUMMINGS, PH.D.
Assistant Professor of Naval Architecture
NORMAN JONES, PH.D.
Assistant Professor of Naval Architecture
ALAA MANSOUR, PH.D.
Assistant Professor of Naval Architecture
JEROME H. MILGRAM, PH.D.
Assistant Professor of Naval Architecture

Senior Lecturer
MIGUEL CHAPERO JUNGER, SC.D. (*Visiting*)

Lecturers
WILLIAM AVERY BAKER, S.B.
BERNHARD WALTER ROMBERG, PH.D. (*Visiting*)

Instructor
JOHN CHARLES ADAMCHAK, S.M.

Research Associate
ERNEST FARNSWORTH BISBEE, PH.D.

Professors Emeriti
EVERS BURTNER, S.B.
Associate Professor of Naval Architecture and Marine Engineering, Emeritus
JACOB PIETER DEN HARTOG, PH.D., D.ENG., D.APPL.SC., D.TECH.SC.
Professor of Mechanical Engineering, Emeritus; Senior Lecturer
FRANK MENDELL LEWIS
Professor of Marine Engineering, Emeritus; Senior Lecturer
HENRY EASTIN ROSSELL, S.M.
Professor of Naval Construction, Emeritus

NAVAL ARCHITECTURE AND MARINE ENGINEERING

The Department of Naval Architecture and Marine Engineering encompasses ocean transportation, naval engineering, and ocean engineering. It is concerned with all aspects of vehicles and structures operating below and just above the sea surface, as well as on it. Activities range from the application of the most advanced engineering science disciplines to the unusual and specialized problems encountered in such devices; through the synthesis of all the systems, components, and structures of which they are comprised; to the consideration of environmental effects; to fabrication and construction; and to the management of transportation enterprises. The unifying objective is that of optimizing the sea-based components of transport, utilization, and habitation systems, whether in their research, development, or production phases. In keeping with this purpose, the Department of Naval Architecture and Marine Engineering emphasizes both the application of scientific knowledge and the development of each student's ability to interpret and apply the rapidly expanding knowledge in all pertinent disciplines.

Among the specific interests of the Department is the development of vehicles, structures, and devices for undersea research and exploitation. Deep-submergence, hydrofoil, and air-cushion vehicles present intriguing and urgent problems in structural and hydrodynamic design, propulsion, control, and instrumentation. Large structures for the recovery of petroleum and mineral resources from the ocean floor also fall largely into the field of interest of naval architects. Interest in devices for oceanographic research is generated by the close alliance between physical oceanography and the environmental conditions to which other vehicles and structures are subjected. Challenging applications of operations research are to be found in the evaluation of environmental conditions, in design, and in management.

The educational program of the Department leads to a broad engineering and scientific competence, with a core content which includes application of fundamental principles to problems in ocean transportation, naval engineering, and ocean engineering. It is based on a wide-ranging foundation of fundamental engineering 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 research and industrial experience, and unusually close faculty-student contact all contribute to a sound and effective education.

The Department offers programs at both the undergraduate and graduate level in Naval Architecture and Marine Engineering, including a graduate degree program in Ocean Engineering. A program in Shipping and Shipbuilding Management is offered as a combination of undergraduate and graduate study, or as a graduate program. In addition, a program in Naval Construction and Engineering is available to selected officers of the U.S. Navy, U.S. Coast Guard, and accredited foreign navies.

THE UNDERGRADUATE PROGRAMS

Naval Architecture and Marine Engineering (Course XIII)

This curriculum is intended for students interested in the technical aspects of the marine industry — naval architects, marine engineers, and those with more specialized interests such as hydrodynamics. It also serves as suitable preparation for (and may be integrated with) the graduate programs in Ocean Engineering and in Shipping and Shipbuilding Management. All take the same required subjects in mathematics, science, engineering fundamentals, and humanities, in addition to subjects in the various phases of vehicle design, construction, and marine engineering. In each of the latter, attention is focused on the flexible and creative application of science and 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 about six subjects (in addition to those normally taken in the first two years), 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 design, ocean engineering, management, hydrodynamics, and structural mechanics. 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 elective subjects can result. Sequencing of required and

prerequisite subjects can be so arranged that whatever normal program has been followed at the Institute during the first two years, the departmental undergraduate requirements can be met in a total of four years by foregoing elective time in the upperclass years.

Within departmental subjects, emphasis is placed on the application of engineering and science to physical problems, with examples chosen principally from the fields of naval architecture, marine engineering, ocean transportation, and ocean engineering; design projects emphasize the underlying engineering principles. Throughout, attention is directed to the development of logic and originality, to the end that graduates may make an effective attack on any engineering problem. 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 99*)					
	Specific science and humanities and social science subjects				**128**
	ECONOMIC PRINCIPLES I (14.01) is required in the upperclass humanities and social science program.				
	The subjects 2.01, 8.03T, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement (see page 49).				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects[1]				
2.01	MECHANICS OF SOLIDS	4	0	8	
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8	
2.201	FLUID MECHANICS	4	0	8	
2.403	THERMODYNAMICS	4	0	8	
3.141	SCIENCE OF MATERIALS	4	3	5	
8.03T	PHYSICS III	5	0	7	
13.00T	PRINCIPLES OF NAVAL ARCHITECTURE	3	1	8	
13.10	SHIP STRUCTURAL ANALYSIS AND DESIGN	4	0	8	
13.20	ENERGY CONVERSION SYSTEMS AND COMPONENTS	4	0	8	
13.40	INTRODUCTORY SHIP DESIGN	1	6	5	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
	THESIS		9		
					153
	Unrestricted Electives[2]				**67**
Total units required for the S.B. degree					**360**

[1] The Department encourages substitution of subjects of similar content after consultation with and concurrence of the Faculty Counselor.

[2] Schedules of students in Course XIII may always be arranged to leave available 12 units of unrestricted elective in the second year.

Shipping and Shipbuilding Management (Course XIII-B)

This five-year program is intended for students primarily interested in the business and management phases of the marine industry. Students entering professional work in 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 the Department of Economics and the Alfred P. Sloan School of Management.

The coordinated program of undergraduate electives and graduate study for Course XIII-B will be approved after consultation with and concurrence of the Alfred P. Sloan School of Management. Compliance with all regulations of the Graduate School is required.

Although students are not normally admitted to the program until application to the Department at the end of the third year, it will be found convenient to arrange elective programs throughout the undergraduate period of study with this end in view because interdepartmental requirements of graduate subjects in economics and industrial management make early use of elective time for prerequisites necessary. Completion of the prescribed program within five years can be accomplished only by the most effective use of elective time. Application for admission to the Graduate School must be accepted before the beginning of the fifth year. Satisfactory scores in the Admissions Test for Graduate Study in Business must be submitted.

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 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 72 units of graduate study plus a satisfactory thesis. Normally, students will fulfill prerequisites for required subjects by taking additional graduate subjects.

The graduate program in Shipping and Shipbuilding Management is described below.

GRADUATE STUDY IN NAVAL ARCHITECTURE, MARINE ENGINEERING, OCEAN ENGINEERING, AND SHIPPING AND SHIPBUILDING MANAGEMENT

Graduate study may be pursued in one or more of the following areas: Naval Architecture, Marine Engineering, Ocean Engineering, Naval Engineering, and Shipping and Shipbuilding Management.

A program of graduate study in the Department is almost entirely under the control of the student, with assistance in his planning by his Graduate Registration Officer. An acceptable graduate program of 72 credit units plus an acceptable thesis leads to the degree of Master of Science in Naval Architecture and Marine Engineering or in Ocean Engineering; this program can usually be completed in one academic year if it is based on an undergraduate curriculum equivalent in scope and emphasis to that available in this Department. A two-year program leads to the degree of Naval Architect, Marine Mechanical Engineer or Ocean Engineer. Students with a less suitable undergraduate background will 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 or Doctor of Philosophy usually requires a minimum of three years of graduate work if the thesis can be completed in one year. Specialization in any aspect of naval architecture, marine engineering, or ocean engineering is appropriate.

Subjects in this Department which are appropriate to the programs of civilian graduate students include the following areas:

HYDROMECHANICS (13.02, 13.03, 13.04, 13.05, 13.06, 13.07)
STRUCTURAL MECHANICS (13.11, 13.12, 13.13, 13.14, 13.15, 13.17, 13.18, 13.19)
POWER AND PROPULSION (13.21)
DESIGN (13.41, 13.42)
COMPUTATION (13.50, 13.51)
OCEAN TRANSPORTATION (13.23, 13.47J, 13.60, 13.61, 13.62, 13.65)
OCEAN ENGINEERING (13.92J, 13.95, 13.97, 13.98, 13.99)
SPECIAL SUBJECTS (13.71, 13.72)

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, oceanography, random processes, decision theory and optimization techniques, 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
Power and propulsion
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 are not acceptable to the Department in partial fulfillment of the advanced degree requirements. Somewhat less broad undergraduate work is appropriate for candidates for the degree of Master of Science without specification, if accompanied by correspondingly increased competence in areas pertinent to the proposed graduate program.

Departmental Requirements for Advanced Degrees

The program of studies for an advanced degree 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 are expected to include in their programs at least one term of advanced mathematics beyond the requirements of the Department's undergraduate curriculum. The program for an S.M. degree must include a minimum of 72 subject units plus a thesis acceptable to the Department. A minimum of 48 of the 72 units must be "A" subjects.

The S.M. degree thesis should represent the equivalent of a half term of full-time work.

A program for an Engineer degree ordinarily includes two subjects in the area of economics, industrial management, or political science, and at least 12 units of comprehensive design, such as DESIGN OF A WATERBORNE VEHICLE (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 specifications of both degrees. Additional departmental requirements applicable to each of the S.M. and Engineer degrees are available from the Department Graduate Office.

In addition to the Institute requirements for the doctoral program, the Department requires the successful completion of qualifying examinations before a student is admitted to a doctoral program. The programs of students must be acceptable to the Departmental Committee on Graduate Students, both as to depth in the major area and broadness in collateral areas. Details of the examination and other special departmental requirements, including those for the doctoral thesis, may be obtained from the Department Graduate Office.

The Department interprets the field of naval architecture and marine engineering rather broadly in connection with the requirements for a degree with or implying such 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 or marine engineering.

Assistantships and Graduate Scholarships

A limited number of teaching and research assistantships are available in the Department each year. These are awarded on the basis of both qualification and need. Departmental policy is that each assistant is expected to devote a minimum of 20 hours per week to his official duties; these duties contribute directly to the assistant's educational program. In accord with this policy, maximum registration for an assistant is limited to 36 units per term if there is no thesis registration. If an assistant is registered for thesis, the maximum number of subject units will be reduced in accordance with the anticipated thesis load. An exception to this policy will be permitted when thesis research directly contributes to the official duties of the assistant.

M.I.T. fellowships and scholarships, and National Science Foundation grants awarded on recommendation of the Department are available. In addition, 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 or in the shipping industry, 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 Graduate Fellowships are made directly to that Society. Inquiries for the fall term should be made late in the preceding fall 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 full-time study at the Institute for eight terms, the Course includes appropriate experience during the summer after the second year.

The Course leads to the degree of Naval Engineer or Master of Science in Naval Architecture and Marine Engineering. For programs leading to the Naval Engineer degree, a Master of Science degree is awarded simultaneously upon recommendation of this Department or of the Department represented by the student's specialty.

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.

Shipping and Shipbuilding Management Course (XIII-B)

The educational objectives of the five-year program in Shipping and Shipbuilding Management, previously described, may also be achieved by post-baccalaureate study. In addition to satisfaction of departmental requirements for the undergraduate curriculum in Naval Architecture and Marine Engineering, students select areas of concentration in management, operations, or control. They study undergraduate and graduate subjects in the Department of Economics, the Alfred P. Sloan School of Management, and the Department of Naval Architecture and Marine Engineering. They may also broaden their experience by electing advanced subjects offered by other departments at the Institute.

Requirements for admission to the graduate program in Shipping and Shipbuilding Management are the same as for other graduate study in the Department, as stated above, with the addition that scores in the Admissions Test for Graduate Schools of Business must be submitted. Students entering the program at the graduate level should expect to devote two years to completing requirements for the degree of Master of Science in Shipping and Shipbuilding Management, in view of the prerequisites necessary. The graduate subjects required for the degree are established after consultation with and concurrence of the Alfred P. Sloan School of Management. All general requirements of the Department for the award of advanced degrees as specified above must be satisfied.

Engineering

DEPARTMENT OF NUCLEAR ENGINEERING

Department of Nuclear Engineering

MANSON BENEDICT, PH.D. (*Absent*)
Professor of Nuclear Engineering; Head of the Department
ELIAS PANAYIOTIS GYFTOPOULOS, SC.D.
Professor of Nuclear Engineering; Acting Head of the Department
ALLEN F. HENRY, PH.D.
Professor of Nuclear Engineering (Visiting)
IRVING KAPLAN, PH.D. (*Absent*)
Professor of Nuclear Engineering
EDWARD ARCHIBALD MASON, SC.D.
Professor of Nuclear Engineering
NORMAN CARL RASMUSSEN, PH.D.
Professor of Nuclear Engineering
DAVID JOHN ROSE, PH.D.
Professor of Nuclear Engineering
THEOS JARDIN THOMPSON, PH.D.
Professor of Nuclear Engineering; Director of the M.I.T. Reactor
GORDON LEE BROWNELL, PH.D.
Associate Professor of Nuclear Engineering
FRANKLYN MILES CLIKEMAN, PH.D.
Associate Professor of Nuclear Engineering
THOMAS HENDERSON DUPREE, PH.D.
Associate Professor of Nuclear Engineering
HENRI FENECH, SC.D.
Associate Professor of Nuclear Engineering
KENT FORREST HANSEN, SC.D.
Associate Professor of Nuclear Engineering
LAWRENCE MARK LIDSKY, PH.D.
Associate Professor of Nuclear Engineering
THOMAS OWENS ZIEBOLD, PH.D
Associate Professor of Nuclear Materials
SOW-HSIN CHEN, PH.D.
Assistant Professor of Nuclear Engineering
MICHAEL JOHN DRISCOLL, SC.D.
Assistant Professor of Nuclear Engineering
N. THOMAS OLSON, PH.D
Assistant Professor of Nuclear Engineering; Postdoctoral Fellow in Engineering
SIDNEY YIP, PH.D.
Assistant Professor of Nuclear Engineering

Lecturers

LEON EDWARD BEGHIAN, PH.D.
SAMUEL LEVIN, S.B.

Research Associates

EDWARD JAMES BARNETT
RONALD ALFRED BLANKEN, M.A.
LINCOLN CLARK, JR., A.B., S.M.
JAMES WATERBURY GOSNELL, M.S.

NUCLEAR ENGINEERING

The Department of Nuclear Engineering provides advanced technical education for students interested in developing the peaceful applications of nuclear reactions and plasma physics. In keeping with M.I.T.'s traditional role in other branches of knowledge, the Department aims to educate the individuals who will make the key scientific and engineering advances in these fields. Although the technological problems of power generation by neutron-induced fission of heavy elements in nuclear reactors and fusion of light particles in thermonuclear plasmas receive primary emphasis in the Department, the totality of its interests is best described as the engineering physics of low-energy charged and neutral particles.

Fission reactors are used to produce heat and electricity, to propel submarines and ships, and to transmute elements and produce radioisotopes. The most important development now occurring in the fission field is the rapid growth in the number and capacity of electric generating stations using nuclear fission reactors as heat sources. Nuclear power is already economically competitive with power from coal, oil, or gas in many regions of the United States and in many foreign countries. One challenging task facing today's nuclear engineers is reducing the capital cost of nuclear power stations and extending the life of nuclear fuels so that nuclear plants will become the most economic way of generating electricity in ever-widening regions of the world. These cost reductions can be realized by intelligent interpretation of the performance of today's reactors, by development of improved methods for designing tomorrow's reactors, and by conceiving new and better types of reactors than any now in use.

Another assignment to challenge nuclear engineers is the development of economic breeder reactors which will derive their energy from fission of abundant uranium-238 or thorium instead of from the relatively scarce isotope uranium-235, which is the principal fissionable material in presently operating reactors. Breeder reactors will provide an energy resource capable of supplying the needs of the world for millions of years.

Fission reactors find widespread use in research on the interaction of radiation and matter and in the production of radioisotopes and the transmutation of elements. Also, the large amount of energy obtainable per unit mass of

fissile fuel and the fact that air is not needed to sustain the fission reaction make fission reactors especially valuable in submarine and space applications.

The Department's interest in plasma physics originated in investigations of the problem of controlled fusion of light elements in a thermonuclear plasma. Development of a practical and economic means of producing power from controlled fusion would provide the world with another practically inexhaustible source of energy. These interests have now broadened to include fundamental studies of plasmas, and other applications. For controlled nuclear fusion with its requirement for confining a large volume of gas at a temperature of many millions of degrees without appreciable loss, further basic studies are certainly necessary before questions of feasibility can be answered. In addition, the same principles lead to much-needed understanding of astrophysical and ionospheric phenomena, magnetohydrodynamic energy conversion, ion propulsion, direct-conversion thermionic diodes, and high-power gas lasers. The latter two topics are applications of particular present interest in the Department. Students of the Department concentrating on applied plasma physics are therefore trained not only to advance knowledge of controlled fusion and of the plasma field as a whole, but also to apply the fundamental science in other contexts of more immediate practical significance. In these plasma activities, the Department is an active participant in M.I.T.'s broad, interdepartmental program of research and instruction in plasma physics and its varied applications.

Paralleling its work on these two important nuclear reactions, the Department of Nuclear Engineering offers two principal options for graduate study and research, the fission technology option and the applied plasma physics option. In each option, programs are available leading to the degrees of Master of Science in Nuclear Engineering, Nuclear Engineer, and Doctor of Science or Doctor of Philosophy. No undergraduate degree is offered.

In these programs attention is focused on the technology of the fission reaction and plasma phenomena and on aspects of physical sciences and engineering which contribute importantly to the efficient development of these fields, as, for example, low-energy nuclear physics, plasma physics, nuclear materials, and high-flux heat transfer. The Department follows a broad interdisciplinary approach, making use of important segments of physics, chemistry, and metallurgy and drawing on the techniques of chemical, civil, electrical and mechanical engineering where relevant to the solution of nuclear engineering problems. The program in nuclear engineering at M.I.T. is open to students with undergraduate training in these and related fields. It aims to teach the basic principles of nuclear technology and applied plasma physics and to show each student how his field of undergraduate specialization may be applied to problems in these fields. 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 developments or plasma applications.

RESEARCH FACILITIES

The Department's educational program is supported by a number of outstanding experimental facilities for advanced research in nuclear engineering.

THE M.I.T. RESEARCH REACTOR

The M.I.T. Research Reactor operates at a power of 5000 kw. It is 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 in which the reactor is being used include: neutron physics, cross-section measurements, reactor physics, solid-state studies based on neutron diffraction, radiochemistry, physics of neutron-capture processes, activation analysis, research with short-lived radioisotopes, radiation-catalyzed chemical reactions, radiation-induced biological effects, radiation therapy, and studies of radiation effects on materials.

EXPERIMENTAL PLASMA FACILITIES

The Department utilizes extensive experimental facilities for production and confinement of large volumes of highly ionized plasmas and for studies of plasma turbulence, particle motions, and other phenomena. High-power lasers and other equipment are available both for plasma diagnostics

and for study of basic physical interactions. Experimental apparatus for thermionic conversion studies is also available. The Department has facilities to support a unique program of controlled fusion engineering studies and has its own well-equipped graduate laboratory for instruction in plasma laboratory techniques.

Most of the research on plasmas and controlled fusion is done in M.I.T.'s Research Laboratory of Electronics. This Laboratory is an association of faculty and graduate students from many departments, and it includes groups active in all aspects of plasma research.

OTHER RESEARCH FACILITIES

The Department has a well-equipped nuclear instrumentation laboratory, a 3.5 MeV pulsed Van de Graaff accelerator, a 14 MeV neutron source, and two subcritical natural-uranium reactors, one moderated by water and the other by graphite. Laboratory space and shop facilities are available for research in all areas of nuclear engineering. M.I.T.'s IBM Type 7094 and 360/65 digital computers are used extensively in research and graduate instruction. The Department has its own liquid helium refrigeration unit.

UNDERGRADUATE PREPARATION FOR NUCLEAR ENGINEERING

An undergraduate degree in physics, chemistry, or metallurgy or chemical, civil, electrical, or mechanical engineering furnishes suitable preparation for graduate study in nuclear engineering. Optimum undergraduate preparation would include the following material:

Physics: At least two years, including mechanics, heat, light, electricity, and magnetism and an introduction to wave mechanics and modern physics, equivalent to M.I.T. subjects 8.01, 8.02, 8.03T, and 8.04. Students electing the applied plasma physics option should have more advanced preparation in electricity and magnetism, including facility with Maxwell's equations, preferably equivalent to M.I.T. subject 8.07.

Mathematics: At least two and a half years, including ordinary and partial differential equations, vector analysis, matrix algebra, orthogonal functions, Bessel and Legendre functions, Fourier and Laplace transforms, and an introduction to functions of a complex variable, equivalent to M.I.T. subjects 18.01, 18.02, 18.034, 18.05 and 18.06.

Chemistry: One year of general, inorganic, and physical chemistry, including the periodic table, valence, oxidation-reduction potentials, equilibrium constants, and heterogeneous equilibrium, equivalent to M.I.T. subjects 5.01 and 5.60.

Engineering Fundamentals: Elementary theory of elasticity, thermodynamics of power cycles, and heat transfer, equivalent to M.I.T. subjects 2.01, 2.403 and 2.50.

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. Applicants for admission are advised, but not required, to take the Graduate Record Examination.

GRADUATE STUDY IN NUCLEAR ENGINEERING (COURSE XXII)

Details of the requirements for graduate degrees are given in the following paragraphs.

MASTER OF SCIENCE IN NUCLEAR ENGINEERING

The object of the Master's degree program is to give the student as good general knowledge of either the fission or the applied plasma aspects of nuclear engineering as can be gained in one year of full-time graduate study. This will provide a good foundation either for productive work in the nuclear field or for more advanced graduate study.

The general requirements for this degree are listed in Section 3 of this Catalogue. Subjects recommended 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 (22.231)
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)
NUCLEAR PHYSICS FOR ENGINEERS I (8.721T)
NUCLEAR PHYSICS FOR ENGINEERS II (8.722T)

Depending on the student's particular interests, additional subjects should be selected from:

ECONOMICS OF NUCLEAR POWER (22.27)
NUCLEAR PLANT DYNAMICS (22.242)
NUCLEAR REACTOR DESIGN (22.26)
NUCLEAR ENGINEERING FOR SPACE APPLICATION (22.232)
NUCLEAR CHEMICAL ENGINEERING (22.31)
NUCLEAR REACTOR OPERATIONS (22.42T)
RADIATION SHIELDING (22.54)
PLASMAS AND CONTROLLED FUSION (22.61)
METALLURGY FOR NUCLEAR ENGINEERS (22.71)
RADIATION AND RADIOISOTOPE APPLICATIONS (22.81)

Subjects recommended for candidates electing the thermonuclear plasma option are:

NUCLEAR REACTOR PHYSICS I (22.21)
PLASMAS AND CONTROLLED FUSION (22.61)
ADVANCED PLASMA PRINCIPLES (22.62)
ENGINEERING PHYSICS OF PLASMA AND PARTICLE DEVICES (22.63)

PLASMA LABORATORY (22.65)
NUCLEAR PHYSICS FOR ENGINEERS I (8.721T)
NUCLEAR PHYSICS FOR ENGINEERS II (8.722T)

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.

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 162 units plus thesis must be approved by the Department and should provide a broad education for creative work in the field of nuclear engineering.

This program includes the completion of a substantial engineering design and/or construction project, the record of which will generally form an Engineer's thesis. A suitable Master's thesis may be accepted partly or wholly in place of the Engineer's thesis, and either thesis may be augmented by work done while registered for SPECIAL PROBLEMS IN NUCLEAR ENGINEERING (22.90).

DOCTOR OF SCIENCE OR DOCTOR OF PHILOSOPHY

The program of study leading to these degrees aims to give a comprehensive knowledge of nuclear engineering and to develop competence in advanced engineering research.

General requirements of the Institute for the doctorate are given in Section 3 of the General Catalogue and in the Graduate School Manual. The specific requirements of the Department of Nuclear Engineering are presented here. The four principal parts of the doctoral program are the Major program leading to the General Examination, the Minor program, the language requirement and the doctoral thesis. Upon a satisfactory completion of this program, the student will ordinarily receive the degree of Doctor of Science unless he requests the degree of Doctor of Philosophy. The requirements for both degrees are the same.

The object of the Major program is to give the student good general knowledge of nuclear engineering, together with detailed familiarity with the specific field in which he intends to undertake research. To this end, before the student may start his doctoral research, he is required to pass a general examination demonstrating adequate undergraduate preparation in physics, chemistry, mathematics and engineering fundamentals and comprehensive knowledge at the graduate level of his chosen field in nuclear engineering.

Graduate subjects on which all candidates for the doctorate are also examined include:

NUCLEAR REACTOR PHYSICS I (22.21)
NUCLEAR PHYSICS FOR ENGINEERS I (8.721T)
NUCLEAR PHYSICS FOR ENGINEERS II (8.722T)
PLASMAS AND CONTROLLED FUSION (22.61)

Candidates for the doctorate who elect the fission option must also be familiar with the content of:

NUCLEAR REACTOR PHYSICS II (22.22)
NUCLEAR REACTOR ENGINEERING (22.231)
NUCLEAR REACTOR PHYSICS LABORATORY (22.41)

Candidates who elect the applied plasma physics option should also be familiar with the content of:

ELECTROMAGNETIC THEORY (8.311T)
ADVANCED PLASMA PRINCIPLES (22.62)

and the basic subjects relevant to their particular interest (e.g., fusion plasma research or plasma kinetic theory). The faculty should be consulted when deciding upon a reasonable study program. The doctoral examination will also include elective questions on other related subjects.

The object of the Minor program is to broaden the student's knowledge. The Minor consists of completing satisfactorily two or more related subjects, totaling at least 24 credit units, in a field other than nuclear engineering and of a more advanced character than would have been required for the student's undergraduate degree. The Minor program should be arranged in consultation with the student's registration officer, and have his approval. Graduate level subjects taken at other schools may be used to satisfy the Minor requirement if the registration officer judges them to be equivalent to M.I.T. graduate subjects.

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, nuclear metallurgy, feedback control, heat transfer, nuclear instrumentation, shielding, transport theory, nuclear chemistry, direct con-

version 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, treatment of radioactive wastes; plasma physics, magnetohydrodynamics, fusion energy recovery, charged particle transport theory, plasma propulsion, plasma production and confinement, thermionic energy conversion, and gas laser technology.

Center for Advanced Engineering Study

HAROLD SOMERS MICKLEY, SC.D.
Ford Professor of Chemical Engineering; Director of the Center for Advanced Engineering Study
PAUL EDWARD BROWN, SC.D.
Executive Officer of the Center for Advanced Engineering Study
JOHN TOWNSEND FITCH, B.S.
Manager, Self-Study Subject Development
WILBUR BAYLEY DAVENPORT, JR., SC.D.
Professor of Electrical Engineering
HERBERT IRVING GROSS, B.A.
Senior Lecturer in Civil Engineering
WILLIAM WEED KAUFMANN, PH.D.
Professor of Political Science
GEORGE WILLIAM RATHJENS, PH.D.
Professor of Political Science (Visiting)
HARRY LESLIE VAN TREES, JR., SC.D.
Associate Professor of Electrical Engineering
RICHARD LAWRENCE DENEUFVILLE, PH.D.
Assistant Professor of Civil Engineering
JOSEPH MARTIN SUSSMAN, PH.D.
Assistant Professor of Civil Engineering
STEVEN DAVID ROSENBERG, E.E.
Instructor in Political Science

FACULTY ADVISORY COMMITTEE

JUDSON RICHARD BARON, SC.D.
Professor of Aeronautics and Astronautics
MYLE JOSEPH HOLLEY, JR., S.M.
Professor of Civil Engineering
LOUIS DIJOUR SMULLIN, S.M.
Professor of Electrical Engineering; Head of the Department of Electrical Engineering
HENRY MARTYN PAYNTER, SC.D.
Professor of Mechanical Engineering
IRVING KAPLAN, PH.D.
Professor of Nuclear Engineering
GEORGE EDWARD VALLEY, JR., PH.D.
Professor of Physics

ADVANCED ENGINEERING STUDY

The M.I.T. Center for Advanced Engineering Study was established in order to provide ways for experienced professional engineers and scientists to attain and maintain the competence needed for continued leadership in an age of unparalleled technological change. The Center adds a new dimension to the activities of M.I.T. by offering educational programs which are designed to enable experienced engineers and scientists from industry, government, and educational institutions to acquire the understanding and skills needed to open technical frontiers.

Programs of the Center

The programs of the Center include the Practicing Engineer Advanced Study Program described below, the Systematic Policy Analysis Program, five- to ten-week programs in specialized areas of science and engineering, interdisciplinary projects concerned with the potential contributions of new and advanced technological developments to important and complex problems, and participation in continued education programs offered on the premises of industrial and government organizations.

The Practicing Engineer Advanced Study Program

The Practicing Engineer Advanced Study Program is planned to enable practicing engineers and scientists to work in depth in technological areas pertinent to their professions. The program of each participant is tailored to his needs. It is thus possible to accommodate the technical manager who wishes to understand those developments that bear directly on his problems, the man who seeks competence in depth at a technological frontier, and the man who desires to strengthen and expand his technological base.

Members of the Program are affiliated with the Center for one or more terms; a two-term sequence is recommended. Each member is associated with a faculty member who acts as his sponsor for the Program and helps arrange activities divided between formal classroom study, tutorial or research study, and other M.I.T. opportunities best suited to the member's needs and background.

The entire offering of M.I.T. undergraduate and graduate subjects, seminars, and colloquia are available. Subjects may be selected from those offered by the Schools of Engineering, Science, Architecture and Planning, Management, and Humanities and Social Science.

Participation in on-going research work may be carried out, and self-study programs with informal tutorial assistance can be arranged. The program of each participant can be largely tailored to his specifications provided it represents a serious intellectual commitment commensurate with his background and professional aims.

SEMINARS AND SPECIAL SUBJECTS

Members of the M.I.T. Faculty conduct weekly seminars in the Center for Advanced Engineering Study during the fall and spring terms; these seminars are planned especially for members of the Practicing Engineer Advanced Study Program. The following special subjects of broad interdisciplinary interest are also offered within the Center for members of the Program:

COMPUTER SYSTEMS (1.156)
PROBABILITY THEORY AND RANDOM PROCESSES (6.579)
SPECIAL SUBJECTS IN ELECTRICAL ENGINEERING (Quantum Mechanics and Its Applications) (6.686 and 6.687)

Special sections of the following subjects are offered for the participants in the Advanced Study Program:

ELEMENTS OF SYSTEMS ANALYSIS (1.146)
ENGINEERING SYSTEMS ANALYSIS (1.147)

Special sections of the following subjects are offered for participants in the Center's Systematic Policy Analysis Program. However, these subjects are also open to the Advanced Study Program participants.

PRINCIPLES OF SYSTEMATIC POLICY ANALYSIS (17.331)
READING SEMINAR IN SOCIAL SCIENCE (Case Studies in Analysis) (17.711)
READING SEMINAR IN SOCIAL SCIENCE (Quantitative Techniques) (17.712)
INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (17.731)
STATISTICS FOR THE SOCIAL SCIENCES (17.732)

Before the fall term starts, participants in the Practicing Engineer Advanced Study Program may attend CALCULUS REVISITED, an optional six-week review offered by the Center to provide an opportunity to strengthen mathematical skills before entering the mainstream of activities of the Center. This review is an intensive development of the first two years of a modern approach to calculus. The point of view adopted is that of the technical professional who intends to apply mathematics to his problems. The aim is to provide the real understanding that supplies the basis for more advanced work and for continued self-development as well as for proficiency.

DEGREES AND GRADES

A certificate will be awarded following satisfactory completion of the Program. Participants who fulfill the requirements of the Graduate School are eligible for advanced degrees. Grades will be recorded for those M.I.T. subjects which are taken for credit.

The Program fee, payable to M.I.T., is $1,800 for the fall or spring term, $3,600 for the two-term school year, $1,400 for the regular summer term, and $700 for CALCULUS REVISITED. The costs of the program are substantially greater than this fee. Initially, each man accepted as a participant will be awarded, from the grant to begin the Program provided by the Alfred P. Sloan Foundation, a scholarship which will supplement the Program fee in meeting M.I.T.'s costs.

The personal and family costs incident to living in Greater Boston for participation in the Program will vary among the men according to their personal circumstances. A personal budget for the year in Greater Boston should include (1) living costs; (2) the extra costs involved in moving; (3) the cost of books and other study materials.

ADMISSION REQUIREMENTS

The primary requisites for admission are evidence of serious intent, intellectual maturity, and the technical background needed for participation, with appropriate guidance, in regular M.I.T. subjects and other scholarly activities at the Institute. Participants will be selected by an M.I.T. committee drawn from faculty members working in areas in which the candidate proposes to study. Application forms are available from the Director of the Center. Applications for the fall term should be received before July 1, for the spring term before December 1, and for the summer term before May 1.



SCHOOL OF HUMANITIES AND SOCIAL SCIENCE 6.

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 consists of five departments, with a faculty of about 125 in the three professorial ranks. Three of these departments are in the social sciences — Economics, Political Science, and Psychology. The two humanistic departments, on the other hand, are multidisciplinary in their scope. Thus the Department of Humanities embraces the fields of history, literature, music, and philosophy, while the Department of Modern Languages and Linguistics is concerned with language skills, literature in foreign languages, and the more technical field of linguistics.

The faculty of this School has three complementary missions. In the first place, it is responsible for much of the general education required of every undergraduate at M.I.T., regardless of his area of specialization. In this role, the Department of Humanities teaches a required sequence of two interdisciplinary term subjects to all freshmen; and the members of that Department are then joined by social scientists in offering a limited number of rather broadly disciplinary subjects in the sophomore year. Some of these freshman and sophomore subjects are also available in sections taught exclusively in French and German. Later, all of the faculties of the School meet their share of juniors and seniors, since these upperclassmen are required to elect four additional terms in the humanities or social sciences, including typically a sequence of three terms in a single field chosen from ten available areas. The curriculum for the first two years and the ten fields for subsequent study are described in Section 2 of this Catalogue.

A second mission of the School involves curricula leading to the degree of Bachelor of Science. There are currently such programs in the Department of Economics, the Department of Political Science, and the Department of Humanities. Those in Humanities involve essentially a second major in some branch of either science or engineering, while those in Economics and Political Science are specified as single majors. There is always, however, ample opportunity for each student through the use of free electives to combine a considerable amount of science or engineering with his chosen field of social science if he is so inclined. Even when the student uses his free electives otherwise, there remains of necessity a substantial amount of mathematics and science in his program, as a highly desirable complement to his social science major. In this respect, all of the School's undergraduate degree programs differ substantially from curricula in similar fields at most other institutions.

There are other differences of perhaps greater import. The view is overwhelmingly accepted at M.I.T. that science and engineering are important not only for their own sake but also as

Humanities

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

vital components of modern life and culture. For our own students no less than for all others at the Institute, these disciplines are to be embraced and mastered rather than feared. In other words, no matter what the extent of our students' involvement with science and engineering subjects, the same rigor is expected of them as of their fellow students who are majoring in a field of science or engineering. This is so both for those technical fields that are professionally complementary to study within our own School and also for those aspects of science or engineering that serve only to fill out our own students' general education. Far from regarding scientific study as antithetical to the humanistic or social-scientific, we feel that the essential unity of serious study in any area should be recognized. Accordingly, we hope that our programs are 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 should find that the preparation for modern life afforded by our Courses in economics, political science, or humanities is unique and effective. Alternatively, he should also find himself well prepared for further study in a law school, medical school, or graduate school of business, as well as in a graduate department in the area of his own major in the humanities or social science. And finally, if he has planned his program suitably, he should also find it possible to continue in graduate work in his selected field of science or engineering. Thus our curriculum is an unusually flexible and open-ended one.

The School of Humanities and Social Science accepts with enthusiasm as the third part of its mission a responsibility to contribute to an expansion of the frontiers of knowledge. It does so both through the research and creative scholarship of its faculty and, in a growing number of fields, through programs of graduate study leading to the doctorate. These activities are prized not only for their own sake but also as contributing to the quality of undergraduate instruction. 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 through research and study in fields of economics, political science, psychology, linguistics, and philosophy.

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 non-technological institutions. We believe this to be a happy pair of circumstances, which make every part of our student offering richer.

ROBERT L. BISHOP

THE UNDERGRADUATE CURRICULA IN THE SCHOOL OF HUMANITIES

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 science (the General Institute Requirements), and a concentration in one of the humanities or social science disciplines, combined with a group of subjects in science or engineering (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. R.O.T.C. subjects may be used according to the specifications in Section 2.

GENERAL INSTITUTE REQUIREMENTS (*see page 45*)					*Total units*
	Specific Science Subjects				
5.01	CHEMISTRY	5	0	7	
8.01	PHYSICS I	5	0	7	
8.02	PHYSICS II	5	0	7	
18.01	CALCULUS	4	0	8	
18.02	CALCULUS	4	0	8	
					60
	Humanities and Social Science Subjects (*See pages 50–55*)				**68**
					128

Science Distribution Requirement
At least 36 units in three fields (*see page 48*)

Laboratory Requirement
At least 12 units (*see page 49*)

Department of Economics

EDGAR CARY BROWN, PH.D.
Professor of Economics; Head of the Department

MORRIS ALBERT ADELMAN, PH.D.
Professor of Economics

SIDNEY STUART ALEXANDER, PH.D. (*Absent*)
Professor of Economics

JAGDISH NATWARLAL BHAGWATI, PH.D.
Professor of Economics

ROBERT LYLE BISHOP, PH.D.
Professor of Economics; Dean of the School of Humanities and Social Science

EVSEY DAVID DOMAR, PH.D.
Professor of Economics

RICHARD SAMUEL ECKAUS, PH.D.
Professor of Economics

FRANKLIN MARVIN FISHER, PH.D.
Professor of Economics

HAROLD ADOLPH FREEMAN, S.B.
Professor of Statistics

EVERETT EINAR HAGEN, PH.D.
Professor of Economics

CHARLES POOR KINDLEBERGER, PH.D., D.H.C.
Professor of Economics

EDWIN KUH, PH.D.
Professor of Economics

NISSAN LIVIATAN, PH.D.
Professor of Economics (Visiting)

MAX FRANKLIN MILLIKAN, PH.D.
Professor of Economics; Director of the Center for International Studies

FRANCO MODIGLIANI, D.JUR., D.SOC.SCI., LL.D.
Professor of Economics

CHARLES ANDREW MYERS, PH.D.
Professor of Industrial Relations

PAUL NARCYZ ROSENSTEIN-RODAN, DR. RER. POL.
Professor of Economics, Emeritus; Senior Lecturer

JEROME ROTHENBERG, PH.D.
Professor of Economics

PAUL ANTHONY SAMUELSON, PH.D., LL.D., D.LITT., SC.D.
Institute Professor; Professor of Economics

ABRAHAM J. SIEGEL, PH.D.
Professor of Industrial Relations; Associate Dean, Alfred P. Sloan School of Management

ROBERT MERTON SOLOW, PH.D., LL.D. (*Absent*)
Professor of Economics

CARL CHRISTIAN VON WEIZSÄCKER, PH.D.
Professor of Economics (Visiting)

PETER ARTHUR DIAMOND, PH.D. (*Absent*)
Associate Professor of Economics

PETER TEMIN, PH.D.
Associate Professor of Economic History

LESTER CARL THUROW, PH.D.
Associate Professor of Economics

ROBERT WARREN CRANDALL, PH.D.
Assistant Professor of Economics

MATTHEW DAVID EDEL, PH.D.
Assistant Professor of Economics

DUNCAN KARL FOLEY, PH.D.
Assistant Professor of Economics

JOHN REES HARRIS, PH.D. (*Absent*)
Assistant Professor of Economics

CECIL DUNCAN MACRAE, PH.D. (*Absent*)
Assistant Professor of Economics

MICHAEL JOSEPH PIORE, PH.D.
Assistant Professor of Economics

HEDLEY J. B. REES, B.S.
Assistant Professor of Statistics (Visiting)

MIGUEL SIDRAUSKI, PH.D.
Assistant Professor of Economics

Administrative Officer

DELLA LYMAN TAPLEY, A.B.

Instructors

STANLEY FISCHER, M.SC.

CHARLES FREEDMAN, B.A.

Professors Emeriti

PAUL PIGORS, PH.D.
Professor of Industrial Relations, Emeritus

PAUL NARCYZ ROSENSTEIN-RODAN, DR. RER. POL.
Professor of Economics, Emeritus; Senior Lecturer

DONALD SKEELE TUCKER, PH.D.
Professor of Economics, Emeritus

ECONOMICS

This Department is concerned with the scientific study of economic behavior. Such study has long been a part of M.I.T. education, 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 activity. M.I.T. believes that its students, by learning something about the economic environment in which they live and work, will have greater satisfaction in life and become more valuable members of their professions.

THE UNDERGRADUATE CURRICULUM

Economics (Course XIV)

The Course leading to the degree of Bachelor of Science in Economics combines basic training in engineering and science with that in economics. This combination emphasizes the relationships among scientific, engineering, economic, and industrial relations problems, thus giving insight into both the technical and non-technical aspects of an industrial society. Students may prepare for a wide range of careers, particularly in the research, engineering, economics, personnel, sales, production, planning, and international departments of business and in governmental and labor organizations.

More specifically, the objectives of this 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 particular weight placed on these various objectives is then determined primarily by the student's selection of electives.

A wide latitude is offered for students to specialize in a particular area of economics, or to proceed beyond the elementary level in several fields. The unrestricted electives make possible greater concentration in economics than the minimum, more emphasis on science and engineering, and the further exploration of other complementary fields.

Provided students have taken 14.01 and 14.02 by the end of the second year, a normal program can be followed that will permit some considerable depth in electives in the third and fourth year. The most satisfactory sequence consists of intermediate economic theory (14.04T and 14.06T), in the first term of the third year, followed by introductory statistics (14.381) in the second term. Prerequisites for all electives are then satisfied, including econometrics (14.31) and the required economic research seminar (14.39), which requires both a theoretical and quantitative background and provides training for thesis research.

The Department does not specify any science distribution subjects, but strongly recommends that all students take a subject on computer techniques (1.00), and that those with special interest in quantitative economics take further work in mathematics.

The curriculum requirements for the degree of Bachelor of Science in Economics are given below.

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 165*)					
	Specific science and humanities and social science subjects[1]				132
	Science Distribution Requirement (see page 48)				**36**
	Laboratory Requirement (see page 49)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
14.01	ECONOMIC PRINCIPLES I	3	0	5	
14.02	ECONOMIC PRINCIPLES II	3	0	5	
14.04T	INTERMEDIATE MICROECONOMIC THEORY	4	0	8	
14.06T	INTERMEDIATE MACROECONOMIC THEORY	4	0	8	
14.381	STATISTICAL METHOD	3	0	6	
14.39	ECONOMIC RESEARCH SEMINAR	2	0	6	
	THESIS			9	
					66
	Restricted Electives				
	Elective subjects in economics			32	
	Elective subjects in science or engineering			24	**56**
	Unrestricted Electives				**62**
Total units required for the S.B. degree					**360**

[1] Subjects in Field Six (Economics) and Field Eight (Labor Relations) may not be used for the humanities and social science requirement.

GRADUATE STUDY IN ECONOMICS

The Department of Economics offers work leading to the degrees of Master of Science in Economics and Doctor of Philosophy.

Entrance Requirements for Graduate Study

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following pre-

requisites for graduate study in Economics. A student whose deficiencies are of minor extent will be permitted graduate registration while taking appropriate subjects to remove them.

Mathematics. One full year of college mathematics, including at least one term of calculus. Students may remove a deficiency in mathematics by completing a special one-term subject, MATHEMATICS FOR ECONOMISTS (14.101).

Science. One full year of college work in science. A deficiency in science may be removed by completing any suitable one-term subject in science at the Institute.

Humanities and Social Science. At least six semester subjects in English, history, and other humanities or social science subjects equivalent in scope to those included in the undergraduate curriculum of the Institute. These subjects should be in other than the candidate's own professional field.

Professional Subjects. An undergraduate major in economics is ordinarily required for graduate study in economics. Qualified students who have majored in a related field may be admitted, however, if their programs have included an appreciable amount of economics.

Graduate Subjects

The following subjects are given by the Department primarily for graduate students in economics:

Economic theory:
14.121, 14.122, 14.123, 14.124, 14.132, 14.151, 14.451, 14.452.

Economic history:
14.731, 14.732, 14.733, 14.734.

Monetary and fiscal economics:
14.462, 14.463, 14.471, 14.472, 14.474.

Economic development:
14.282, 14.771, 14.772, 14.773, 14.774, 14.782.

Industrial organization and policy:
14.231, 14.271, 14.272, 14.282, 14.291, 14.292.

Statistics and econometrics:
14.371, 14.372, 14.373, 14.374, 14.381, 14.383, 14.384T, 14.386.

International economics:
14.581, 14.582, 14.584, 14.586.

Labor economics and public policy:
14.671J, 14.672J, 14.674J, 14.691J, 14.692J.

Urban economics:
14.572J, 14.573J, 14.574J.

Master of Science in Economics

Most graduate students in the Department are Ph.D. candidates. Under special circumstances, however, admission may be granted to candidates for the S.M. degree.

The general requirements for the Master's degree are given in Section 3. Subjects strongly recommended are:

ECONOMIC ANALYSIS (14.121, 14.122)
THEORY OF INCOME AND EMPLOYMENT (14.451)
ECONOMIC GROWTH AND FLUCTUATIONS (14.452)

Additional subjects may be selected in line with the student's interests. The program of study must be well balanced, however, and meet with the approval of the student's Registration Officer.

Doctor of Philosophy

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 field for all students. One other field, designated as primary, requires more intensive preparation than the remaining three. Among the elective fields are advanced economic theory, monetary economics, fiscal economics, industrial organization, international economics, economic development, urban economics, labor economics and labor relations, economic history, and statistical theory and econometrics. 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.

No stated number of graduate subjects in the Department of Economics is 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 at least one year's research.

Candidates are required to fulfill the language requirement as described in Section 3. The language or languages must have professional significance for the individual candidate.

Students interested in developing professional competence in the economics and planning problems of the city may combine study in the Department of Economics with study in the Department of City and Regional Planning. Depending on background, candidates can expect to take two and a half academic years of work to prepare for the General Examination.

Department of Humanities

RICHARD MATEER DOUGLAS, PH.D.
Professor of History; Head of the Department

HOWARD RUSSELL BARTLETT, B.S., A.M.
Professor of History, Emeritus; Senior Lecturer

SYLVAIN BROMBERGER, PH.D.
Professor of Philosophy

LYNWOOD SILVESTER BRYANT, A.M.
Professor of History

RICHARD LEE CARTWRIGHT, PH.D.
Professor of Philosophy

GIORGIO DIAZ DE SANTILLANA, PH.D.
Professor of the History and Philosophy of Science, Emeritus; Senior Lecturer

CHARLES FRIED, LL.B.
Professor of Philosophy (Visiting)

WILLIAM CHACE GREENE, M.A.
Professor of Literature, Emeritus; Senior Lecturer

EDWARD NEAL HARTLEY, A.M.
Professor of History; Secretary of the Faculty, Institute Archivist

ROY LAMSON, PH.D.
Professor of Literature

KLAUS LIEPMANN
Professor of Music; Director of Music

ROBERT ELLSWORTH MACMASTER, PH.D.
Professor of History and Literature

THOMAS HENRY DONALD MAHONEY, PH.D.
Professor of History

BRUCE MAZLISH, PH.D.
Professor of History

WAYNE O'NEIL, PH.D.
Professor of Literature

HARALD ANTON THRAP OLSEN REICHE, PH.D
Professor of Classics and Philosophy

CYRIL STANLEY SMITH, SC.D.
Institute Professor; Professor of the History of Science and Technology

HUSTON CUMMINGS SMITH, PH.D.
Professor of Philosophy

J. L. TALMON
Ford Professor of Comparative History (Visiting)

JAMES FREDERICK THOMSON, M.A.
Professor of Philosophy

GREGORY TUCKER
Professor of Music; Director of M.I.T. Humanities Series and Chamber Music of M.I.T.

ROBERT SMITH WOODBURY, S.B., A.M.
Professor of the History of Technology

CHARLES THOMAS COLE, A.M.
Associate Professor of Literature (Visiting)

DAVID MAYER EPSTEIN, PH.D.
Associate Professor of Music; Conductor of the M.I.T. Symphony Orchestra

JOSEPH DEE EVERINGHAM, A.M.
Associate Professor of Literature; Director of Drama

JERRY ALAN FODOR, PH.D.
Associate Professor of Philosophy

ROBERT M. FOGELSON, PH.D.
Associate Professor of History and City Planning

EUGENE GOODHEART, PH.D.
Associate Professor of Literature

ALBERT RAMSDELL GURNEY, JR., M.F.A.
Associate Professor of Literature

ARTHUR DANIEL KALEDIN, PH.D.
Associate Professor of History

LOUIS KAMPF, B.A.
Associate Professor of Literature

JERROLD JACOB KATZ, PH.D.
Associate Professor of Philosophy

ALVIN CHARLES KIBEL, PH.D.
Associate Professor of Literature

DAVID BIRD RALSTON, PH.D.
Associate Professor of History

ROBERT REYNOLDS RATHBONE, A.M.
Associate Professor of Literature

ROBERT I. ROTBERG, PH.D.
Associate Professor of History and Political Science

IRVING SINGER, PH.D.
Associate Professor of Philosophy

NATHAN SIVIN, PH.D.
Associate Professor of the History of Science

BARRY BERNARD SPACKS, M.A.
Associate Professor of Literature (Visiting)

JUDITH JARVIS THOMSON, PH.D.
Associate Professor of Philosophy

WILLIAM BRAASCH WATSON, PH.D.
Associate Professor of History

THEODORE WOOD, JR., S.B., A.M.
Associate Professor of Literature

GEORGE JAY BORNSTEIN, PH.D.
Assistant Professor of Literature

BORUCH ALTER BRODY, PH.D.
Assistant Professor of Philosophy

JOHN BUTTRICK, M.S.
Assistant Professor of Music

DIANE SHAVER CLEMENS, PH.D.
Assistant Professor of History

MARTIN DISKIN, PH.D.
Assistant Professor of Anthropology

GERALD BOB DWORKIN, PH.D.
Assistant Professor of Philosophy

NANCY ZILBOORG DWORSKY, PH.D.
Assistant Professor of Literature

ROBERT SCHOFIELD FREEMAN, PH.D.
Assistant Professor of Music

ANDREW RICHARD HAWLEY, PH.D.
Assistant Professor of Literature

ROBERT EDWIN HERZSTEIN, PH.D.
Assistant Professor of History

MARK ALAN LEVENSKY, PH.D.
Assistant Professor of Philosophy

WARREN JORDAN MACISAAC, PH.D.
Assistant Professor of Literature

TRAVIS RHODES MERRITT, PH.D.
Assistant Professor of Literature

Humanities

DEPARTMENT OF HUMANITIES

ARTHUR RICHARD STEINBERG, PH.D.
Assistant Professor of History and Archaeology
JOHN ROBERTSON WATT, PH.D.
Assistant Professor of History
RICHARD WAYNE WERTZ, PH.D.
Assistant Professor of History
FRANK DOMINIC. ZINGRONE, PH.D.
Assistant Professor of Literature

Administrative Officer
RUTH ELEANOR DUBOIS, A.B., S.B.

Lecturers
JOSEPH STANLEY BROWN, M.A.
JOHN COOK, MUS.B. *Organist*
WILLIAM RAYMOND CROUT, M.A.
HANS GUGGENHEIM, M.A.
SANFORD KAYE, M.A.
JUDITH BORODOVKA WALZER, PH.D.

Instructors
DONALD HOWARD BELL, M.A.
NICHOLAS EGELSON, B.A.
CRAIG RALPH EISENDRATH, B.S.F.S.
MICHAEL BREWSTER FOLSOM, M.A.
SIDNEY GOLDFARB, B.A. (*Absent*)
ALLEN GRAUBARD, B.A.
JOHN COWPERTHWAITE GRAVES, A.M.
ROBERT SOLIN LEIKEN, A.B.
JOHN MCNEES, M.A.
MICHAEL VINCENT MILLER, B.S., M.A.
MARY KATHARINE WAKEMAN, M.A.
THOMAS WEISBUCH, B.A.

Administrative Assistant
WARREN ARTHUR SEAMANS, B.S.

Research Associate
HEATHER NAN LECHTMAN, M.A.

Professors Emeriti
HOWARD RUSSELL BARTLETT, B.S., A.M.
Professor of History, Emeritus; Senior Lecturer
JOHN ELY BURCHARD, L.H.D., D.ARCH.
Professor of Humanities, Emeritus;
Dean of the School of Humanities and Social Science, Emeritus
GIORGIO DIAZ DE SANTILLANA, PH.D.
Professor of the History and Philosophy of Science, Emeritus; Senior Lecturer
WILLIAM CHACE GREENE, M.A.
Professor of Literature, Emeritus; Senior Lecturer
WALTER FRANCIS URBACH, A.M.
Associate Professor of Literature, Emeritus

HUMANITIES

In its efforts to achieve a balanced curriculum for all undergraduates, M.I.T. provides both a required and an elective program in history, literature, philosophy, history and philosophy of science, music, and drama in the Department of Humanities.

In addition, the Department of Humanities offers three undergraduate programs which combine the basic subjects in science and engineering with a concentrated program in the humanities; these programs are Humanities and Engineering (Course XXI-A) and Humanities and Science (Course XXI-B, Programs 1 and 2). In addition, there is a graduate program in philosophy leading to the Ph.D. degree.

THE UNDERGRADUATE CURRICULA

Humanities and Engineering (Course XXI-A)
Humanities and Science (Course XXI-B, Program 1)

These two undergraduate Programs in Humanities and Engineering and in Humanities and Science offer a kind of education from which students may go on to graduate study in science, engineering, and humanities; or into teaching, law, linguistics, medicine, business, and a variety of other fields. Graduates of Course XXI are entering an increasing variety of vocations and careers.

Course XXI-A and Course XXI-B, Program 1, have been described as "double majors." Because of the flexibility they provide for choice of electives, especially in the third and fourth years, a student may devote half of his studies to humanities and the remainder to science or engineering, developing special interests in any combination of the two subject areas. Both Programs lead to a Bachelor's degree at the end of senior year; a student may continue for a fifth year to earn a second Bachelor's degree in the particular field of science or engineering which he studied as an undergraduate. In some cases the fifth year may lead to a Master's degree.

Built on the base provided by the Institute's general requirements in mathematics, physics, chemistry, and humanities, each of these Programs provides a curriculum of unusual scope and balance. One part is the undergraduate curriculum of one of the science or engineering departments, shortened through the omission of certain of the more specialized or technical subjects. The other part consists of advanced study in the humanities, chosen by each student

with the advice of his Faculty Counselor from the various disciplines of the Department of Humanities and the Department of Modern Languages and Linguistics. The student chooses one field for concentration: literature (English, American, French, German, Russian, and comparative literature); history and history of science; philosophy; or music. Through judicious use of elective subjects the student may follow his interests beyond the minimum requirements of the curriculum.

In the fourth year members of Course XXI-A and Course XXI-B, Program 1, participate in a Humanities Seminar, interdisciplinary in character. The Humanities Seminar examines a single topic from the several perspectives of the students' previous study under the guidance of the Humanities department faculty and visiting professors. In addition, each student receives instruction in the writing of a thesis.

Humanities and Science
(Course XXI-B, Program 2)

This new program, first offered to the class of 1969, provides a concentration or a major in history, literature, philosophy, and music. Like the other branches of Course XXI, it is based on the regular Institute requirements in science and in humanities, but provides a study of the humanities in greater range and depth. The required curriculum consists mainly of eight subjects in a chosen field plus four subjects from related fields of humanities, social science, foreign literatures, linguistics, or visual arts. A further requirement is a seminar, in the junior or senior year, devoted to advanced study in the field. Ordinarily every student in Course XXI-B, Program 2, writes a thesis. Students whose accomplishment is high should be able to qualify for graduate study in their fields in major universities; the Program could also be elected by students who wish to pursue a humanities discipline in greater depth than is ordinarily provided in Courses XXI-A and XXI-B, Program 1. A generous number of electives makes it possible to continue work in science, engineering, humanities, or other fields taught in the Institute, allowing the student to increase the concentration in the discipline chosen or to broaden intellectual interests by studies in fields outside of his concentration. Faculty Counselors in each of the disciplines will help students to arrange suitable programs following both their main lines of interest and future professional objectives.

Course XXI-A leads to the degree of Bachelor of Science in Humanities and Engineering, and both Programs of XXI-B lead to the degree of Bachelor of Science in Humanities and Science. The curriculum for the first year is shown on pages 45–48; the curriculum requirements for the degrees in both Courses are summarized below.

HUMANITIES AND ENGINEERING (COURSE XXI-A)

					Total units
GENERAL INSTITUTE REQUIREMENTS *(see page 165)*					
	Specific science and humanities and social science subjects				**128**
	Science Distribution Requirement (see page 48)				**36**
	Laboratory Requirement (see page 49)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
21.07	HUMANITIES SEMINAR	2	0	8	
	THESIS		14		
					24
	Restricted Electives				
	Elective subjects restricted to one of the Humanities disciplines, e.g., history, literature, philosophy, music, etc.		48		
	Elective subjects restricted to one of the engineering curricula		48		
					96
	Unrestricted Electives				**64**
Total units required for the S.B. degree					**360**

HUMANITIES AND SCIENCE (COURSE XXI-B)
CURRICULUM OF PROGRAM 1

					Total units
GENERAL INSTITUTE REQUIREMENTS *(see page 165)*					
	Specific science and humanities and social science subjects				**128**
	Science Distribution Requirement (see page 48)				**36**
	Laboratory Requirement (see page 49)				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
21.07	HUMANITIES SEMINAR	2	0	8	
	THESIS		14		
					24
	Restricted Electives				
	Elective subjects restricted to one of the humanities disciplines, e.g., history, literature, philosophy, music, etc.		48		
	Elective subjects restricted to one of the science curricula		48		
					96
	Unrestricted Electives				**64**
Total units required for the S.B. degree					**360**

CURRICULUM OF PROGRAM 2

		Total units
GENERAL INSTITUTE REQUIREMENTS *(see page 165)*		
	Specific science and humanities and social science subjects	**128**
	Science Distribution Requirement (see page 48)	**36**
	Laboratory Requirement (see page 49)	**12**

Humanities

DEPARTMENT OF HUMANITIES

COURSE XXI-B *(continued)*

DEPARTMENTAL PROGRAM

	Required Subjects				
	THESIS			14	
					14
	Restricted Electives				
21.071	HISTORY SEMINAR				
	or				
21.072	LITERATURE SEMINAR	2	0	8	
	or				
21.073	PHILOSOPHY SEMINAR				
					10
	Elective subjects restricted to one of the humanities disciplines, e.g., history, literature, philosophy, music, etc.			64	
	Elective subjects in a second discipline of humanities, social science, visual arts, literature in modern foreign languages, or linguistics			32	
					106
	Unrestricted Electives				**64**
Total units required for the S.B. degree					**360**

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.

THE DOCTORAL PROGRAM IN PHILOSOPHY

The program of studies leading to the degree of Doctor of Philosophy is designed to provide comprehensive training in modern philosophy, emphasizing particularly its analytical and scientific aspects. An arrangement is also available whereby selected students may pursue a program in the philosophy of a special science — linguistics, mathematics, physics, psychology — while taking graduate work in that science. To enter the program, the 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 as a candidate for the degree by the Department of Humanities.

DOCTOR OF PHILOSOPHY

Students planning to avail themselves of the arrangement to work on the philosophy of a special science must meet the requirements for admission to graduate study in that science. For all other students, the Department specifies the following prerequisites in place of the general requirements for admission given in Section 3 of this Catalogue:

Mathematics. One full year of college mathematics.

Science. One full year of college work in science.

Humanities. At least six term subjects in literature, history, or other humanities subjects equivalent in scope to those included in the undergraduate humanities curriculum of the Institute.

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.

Before the student may start his doctoral research he is required to pass preliminary examinations demonstrating competence in history of philosophy, philosophy of science, logic, ethics, social and political philosophy, theory of knowledge, philosophy of mind, and philosophy of language.

Candidates for the doctorate are encouraged to take a Minor in a field other than philosophy. Possibilities include linguistics, mathematics, physics, psychology, and other humanities or social sciences. Candidates are also required to fulfill the language requirement as described in Section 3 of this Catalogue.

Department of Modern Languages and Linguistics

WILLIAM FILBERT BOTTIGLIA, PH.D.
Professor of Modern Languages and Humanities; Head of the Department

NOAM AVRAM CHOMSKY, PH.D.
Ferrari P. Ward Professor of Modern Languages and Linguistics

MARTIN DYCK, PH.D.
Professor of German and Humanities

MORRIS HALLE, PH.D.
Professor of Modern Languages

ROMAN JAKOBSON, PH.D.
Institute Professor, Emeritus

WILLIAM NASH LOCKE, PH.D.
Professor of Modern Languages

GEORGE HUBERT MATTHEWS, PH.D.
Professor of Modern Languages

KENNETH L. HALE, PH.D.
Associate Professor of Linguistics

ROBERT EMMET JONES, PH.D.
Associate Professor of French and Humanities

KRYSTYNA POMORSKA, PH.D.
Associate Professor of Russian

JAMES WESLEY HARRIS, PH.D.
Assistant Professor of Spanish

RENÉ PAUL VIKTOR KIPARSKY, PH.D.
Assistant Professor of Linguistics

JOHN ROBERT ROSS, PH.D.
Assistant Professor of Linguistics

Lecturers

PRIMUS BENEDICT BON, B.S., M.A.
MARGARET ZAROODNY FREEMAN, S.M.

Instructors

KRISTINE FORSTER BRECHT, M.A.
RENATA HOFMAN BRIGGS
MAGDA BUKA, B.A.
CATHERINE VAKAR CHVANY, A.B.
ILSE KLEMPERER EVANS, M.A.
STELLA BERGER GREENFIELD, M.A.
CLAIRE JEANNE KRAMSCH, M.A.
URSULA BRIGITTE McCUNE
RENATA BERG PAN, M.A.
ILONA RICARDO, M.A.
MARTHA M. SCHECTER, M.A.
LAURENCE HERBERT SCOTT, M.A.

Administrative Assistant

WARREN ARTHUR SEAMANS, B.S.

Professors Emeriti

ROMAN JAKOBSON, PH.D.
Institute Professor, Emeritus

HERMAN KLUGMAN, PH.D.
Assistant Professor of Modern Languages, Emeritus

RICHARD FELIX KOCH, A.M.
Assistant Professor of Modern Languages, Emeritus

GEORGE ALEXANDROVICH ZNAMENSKY, B.D., ED.M.
Assistant Professor of Russian, Emeritus

MODERN LANGUAGES AND LINGUISTICS

The Department of Modern Languages and Linguistics offers subjects for undergraduate and graduate students in several languages and in linguistics. It also provides a program leading to the degree of Doctor of Philosophy.

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 largely 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 freshman and sophomore humanities subjects provide reading and lectures in French and German, allowing students to use and improve their knowledge of the language while simultaneously satisfying the humanities requirement. These subjects are open to graduates of American secondary schools with three or more years of unusually good achievement in French or German.

A two-term sequence on Dante provides both language study and literary analysis. Four advanced subjects in Spanish literature are offered for undergraduates with an adequate background in Spanish.

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 bear in mind that credit towards graduation will not be given for repeating work offered for admission.

GRADUATE SUBJECTS

One-term 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. Two-term subjects in French, German, Russian, and Spanish (also *open to graduate students only*), stressing the listening, speaking, and reading skills are designed to prepare them for direct contact with countries where those languages are the normal medium of communication. These subjects carry no credit.

The Doctoral Program in Linguistics (Course XXIII)

The program of studies leading to the degree of Doctor of Philosophy 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 and Linguistics as a candidate for the degree.

DOCTOR OF PHILOSOPHY

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.

Science. One full year of college work in science.

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.

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 I (23.731)
LINGUISTIC STRUCTURE (23.752)
INTRODUCTION TO LINGUISTICS II: PHONOLOGY (23.762)
SURVEY OF GENERAL LINGUISTICS I (23.781)
SEMINAR IN LANGUAGE ACQUISITION (23.702)

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 requirements for the Ph.D. degree are indicated in Section 3 of this Catalogue.

Department of Political Science

ITHIEL DE SOLA POOL, PH.D.
Professor of Political Science; Head of the Department

ROBERT COLDWELL WOOD, PH.D. (*Absent*)
Professor of Political Science; Head of the Department

HAYWARD ROSE ALKER, PH.D.
Professor of Political Science

LINCOLN PALMER BLOOMFIELD, PH.D.
Professor of Political Science

FRANK BONILLA, PH.D. (*Absent*)
Professor of Political Science

JOHN FREDERICK COLLINS, PH.D., D.C.L.
Professor of Urban Affairs (Visiting)

FREDERICK WARD FREY, PH.D.
Professor of Political Science

WILLIAM EDGAR GRIFFITH, PH.D.
Professor of Political Science

EVERETT EINAR HAGEN, PH.D.
Professor of Economics and Political Science

ERNST HALPERIN, PH.D.
Professor of Political Science (Visiting)

FRED CHARLES IKLÉ, PH.D. (*Absent*)
Professor of Political Science

HAROLD ROBERT ISAACS, A.B.
Professor of Political Science

HELIO JAGUARIBE GOMES DE MATTOS, LL.B.
Professor of Political Science (Visiting)

WILLIAM WEED KAUFMANN, PH.D.
Professor of Political Science

PAUL KECSKEMETI
Professor of Political Science (Visiting)

DANIEL LERNER, PH.D. (*Absent*)
Professor of Sociology

MAX FRANKLIN MILLIKAN, PH.D.
Professor of Economics, Director of the Center for International Studies

NORMAN JUDSON PADELFORD, PH.D., LL.D.
Professor of Political Science

LUCIAN WILMOT PYE, PH.D.
Professor of Political Science

GEORGE WILLIAM RATHJENS, PH.D.
Professor of Political Science (Visiting)

MYRON WEINER, PH.D.
Professor of Political Science

ALAN ANTHONY ALTSHULER, PH.D.
Associate Professor of Political Science

DONALD LAWRENCE MORTON BLACKMER, PH.D.
Associate Professor of Political Science; Assistant Director of the Center for International Studies

LEONARD J. FEIN, PH.D.
Associate Professor of Political Science

ROBERT I. ROTBERG, D.PHIL.
Associate Professor of History and Political Science

JOHN SELIM SALOMA, III, PH.D.
Associate Professor of Political Science

EUGENE BERTRAM SKOLNIKOFF, PH.D.
Associate Professor of Political Science

JOSEPH WEIZENBAUM, S.M.
Associate Professor of Political Science

SUZANNE BERGER, PH.D.
Assistant Professor of Political Science

FRANK CARLETON COLCORD, JR., PH.D.
Assistant Professor of Political Science

ROY ELIOT FELDMAN, PH.D.
Assistant Professor of Political Science

JACKSON ALFRED GIDDENS, PH.D.
Assistant Professor of Political Science

GEORGE ERIC HANSEN, PH.D.
Assistant Professor of Political Science

WILLARD RAYMOND JOHNSON, PH.D.
Assistant Professor of Political Science

ROSEMARIE STRÄUSSNIG ROGERS, PH.D.
Assistant Professor of Political Science

HARVEY MORTON SAPOLSKY, M.P.A.
Assistant Professor of Political Science

JOHN DAVID STEINBRUNER, PH.D.
Assistant Professor of Political Science

Administrative Officer

ELIZABETH ANNA MARIA TERLINGEN, PHARM.

Lecturers

GEORGE WILLIAM ANGELL, JR., ED.D.
RICHARD HENRY BOLT, PH.D.
DAVID ALAN BOOTH, M.A.
ANTHONY P. M. COXON, PH.D. (*Visiting*)
ALBERT GORDON HILL, PH.D.
JAMES RHYNE KILLIAN, JR., LL.D., SC.D., D.ENG., D.APPL.SCI., ED.D., HH.D.
THOMAS ANDREW LEHRER, A.M.
LOUIS MENAND, III, PH.D.

Instructors

CHRISTOPHER WILLIAMS BEAL, PH.D.
L. WALLACE CLAUSEN, M.A.
MATTHEW ALLEN CRENSON, M.A.
STEVEN DAVID ROSENBERG, E.E.

Humanities

DEPARTMENT OF POLITICAL SCIENCE

POLITICAL SCIENCE

Political science is the systematic study of conflict and interdependence among people as members of society. As such, it explores the roles of man in political conflict situations, the distribution and use of power, and political relations and behavior in groups and institutions. Instruction in the Department aims at providing the professional competence that enables students to analyze, understand, and propose operative solutions to political conflicts of consequence to the national society and international community. Undergraduate and graduate subjects seek to equip each student with skills now available to assemble and structure empirical observations about politics — including opinion surveys, political gaming, and computer simulation. Instruction focuses also on contemporary political conditions, born of sustained technological advance, rapid population increase, and changing economic circumstance as reflected in substantive areas of political science. Finally, within a rapidly expanding and increasingly rigorous discipline, emphasis falls on encouraging the general intellectual attributes of the scholar. Hence the stress is upon empirical and interdisciplinary research to ensure the widest possible grounding in knowledge relating to political behavior.

THE UNDERGRADUATE CURRICULUM

Political Science (Course XVII)

Students concentrating in political science acquire knowledge and skills necessary for understanding political behavior with special emphasis on the increasing range of problems that involve the activities of governmental agencies and political groups in matters of direct concern to science and technology.

There is no rigid program of subjects of instruction in the political science curriculum. Each student's program is worked out with the aid of his Faculty Counselor. 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 of possible concentration, for example, is international relations, where the introductory subject INTERNATIONAL RELATIONS (17.51) is followed by a subject on PRINCIPLES AND PROBLEMS IN AMERICAN FOREIGN POLICY (17.52) and SEMINAR IN INTERNATIONAL POLITICS (17.53). Students in the comparative government field may focus on the United States to include, among other subjects, POLITICAL PSYCHOLOGY (17.15), THE AMERICAN POLITICAL PROCESS (17.21), COMPARATIVE POLITICAL SYSTEMS (17.24), and SEMINAR IN CONTEMPORARY URBAN SOCIOLOGY (17.23). In the field of public policy, appropriate subjects are POLITICAL PARTIES (17.28), POLITICS OF NATIONAL ECONOMIC CONTROL (17.26), BUREAUCRACY (17.27), GOVERNMENT, POLITICS, AND TECHNOLOGY (17.42), and STRUCTURE OF URBAN LIFE (17.22). Other fields cover political communications, politics of developing nations, and U.S. defense policy, including subjects such as EVOLUTION OF STRATEGIC NUCLEAR SYSTEMS (17.31) and EVOLUTION OF FORCES FOR LIMITED WAR (17.32).

Each student majoring in political science writes a thesis on a subject that particularly interests him. Students have opportunities for field study with local political organizations or governmental units. As the student progresses into his senior year, he typically takes some reading seminars and graduate subjects in political science.

The Course leads to the degree of Bachelor of Science in Political Science; the curriculum requirements are given below.

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 165*)		
Specific science and humanities and social science subjects[1]		**128**
Science Distribution Requirement[2] (see page 48)		**36**
Laboratory Requirement (see page 49)		**12**
DEPARTMENTAL PROGRAM		
Required Subjects		
THESIS	9	**9**
Restricted Electives		
Elective subjects in political science		**88**
Unrestricted Electives		**87**
Total units required for the S.B. degree		**360**

[1] Subjects in Field Seven (Political Science) may not be used for the humanities and social science requirement.

[2] 1.00 INFORMATION SYSTEMS (3–3–6) and 18.10 APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES (3–0–9) are suggested.

GRADUATE STUDY IN POLITICAL SCIENCE

The Department of Political Science offers work leading to the degrees of Master of Science in Political Science and Doctor of Philosophy.

Entrance Requirements for Graduate Study

In place of the general requirements for admission given in Section 3 of this Catalogue, the Department specifies the following prerequisites for graduate study 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 and Social Science. At least six semester subjects in English, history and other humanities or social science subjects equivalent in scope to those included in the undergraduate curriculum of the Institute. These subjects should be in other than the candidate's own professional field.

Students may remove a deficiency in mathematics by completing a special one-term subject, INTRODUCTION TO MATHEMATICAL MODELS IN THE SOCIAL SCIENCES (17.731), and one other term of mathematics in such subjects as STATISTICS FOR THE SOCIAL SCIENCES (17.732). A deficiency in science may be removed by completing any suitable one-term 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.

Graduate Subjects

The following subjects are given by the Department primarily for graduate students in political science and related fields:

Political Communication and Behavior:
17.111, 17.112, 17.121, 17.122, 17.131, 17.151, 17.161, 17.162, 17.163, 17.191, 17.192.

Comparative Politics:
17.211, 17.213, 17.214, 17.215J, 17.216, 17.221, 17.222, 17.223, 17.224, 17.225, 17.232, 17.241, 17.242, 17.261, 17.262, 17.263, 17.264, 17.265, 17.266, 17.267, 17.271, 17.282.

Defense Policy:
17.311, 17.312, 17.322, 17.331, 17.332, 17.342, 17.352.

Science and Public Policy:
17.412T, 17.413, 17.422, 17.431, 17.442, 17.443J.

International Relations and Foreign Policy:
17.511, 17.513, 17.514, 17.516, 17.521, 17.522, 17.523.

Political and Economic Development:
17.611, 17.612, 17.621, 17.623, 17.631, 17.652.

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 POLITICAL SCIENCE

Most graduate students in the Department are Ph.D. candidates. Under special circumstances, however, admission may be granted to candidates for the S.M. degree.

The general requirements for the Master's degree are given in Section 3. Subjects are wholly elective and are not restricted to those given by the Department. The program of study must be well balanced, however, and meet with the approval of the student's Registration Officer.

DOCTOR OF PHILOSOPHY

A candidate for the doctorate must prepare himself for a General Examination covering three approved fields. In addition, he is examined on the general area of political analysis including political theory and research methods. Established fields include: political communication and behavior, comparative politics, defense policy, science and public policy, international relations and foreign policy, and political and economic development. Approved combinations of some of these fields 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. Guided field research and close working ties with faculty members engaged in major research activities are stressed.

General Requirements for Doctoral Candidates

No stated number of graduate subjects in the Department of Political 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 and emphasizes personal gathering, assembly, and interpreting of source data often collected in the field.

Candidates are required to fulfill the language

requirement as described in Section 3. The language or 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 Psychology

HANS-LUKAS TEUBER, PH.D.
Professor of Psychology; Head of the Department
RICHARD MARX HELD, PH.D.
Professor of Experimental Psychology
BELA JULESZ, PH.D.
Professor of Experimental Psychology (Visiting)
WALLE JETZE HARINX NAUTA, M.D., PH.D.
Professor of Neuroanatomy
STEPHAN LEWIS CHOROVER, PH.D.
Associate Professor of Psychology
JERRY ALLEN FODOR, PH.D.
Associate Professor of Psycholinguistics
ALAN HEIN, PH.D.
Associate Professor of Psychology
PETER HARKAI SCHILLER, PH.D.
Associate Professor of Psychology
WAYNE ALLEN WICKELGREN, PH.D.
Associate Professor of Psychology
MERRILL FREDERICK GARRETT, PH.D.
Assistant Professor of Psychology
WHITMAN ALBIN RICHARDS, PH.D.
Assistant Professor of Psychology
GERALD EDWARD SCHNEIDER, PH.D.
Assistant Professor of Psychology

Instructor
MITCHELL B. LAZARUS, S.M.

Administrative Assistant
ROBERT IRWIN McELROY, B.A.

Research Associates
JOSEPH ALOYSIUS BAUER, M.S.
SUZANNE HAMMOND CORKIN, PH.D.
RHEA MENDOZA DIAMOND, PH.D.
LENNART HEIMER, M.D.
HARVEY JULES KARTEN, M.D.
RITA GILLIS RUDEL, PH.D.
THOMAS EVANS TWITCHELL, M.D.
HANS JAKOB ZEIER, PH.D.

PSYCHOLOGY

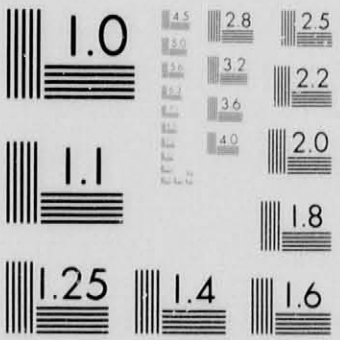
Psychology, the study of behavior, has grown in recent years with unforeseen rapidity. New avenues of approach have been opened by convergent developments of methods in the natural and social sciences and in mathematics, raising the hope that man, who has achieved considerable mastery over the world around him, might also come closer to an understanding of himself.

Psychology at M.I.T. stresses its connections with basic science and concentrates its efforts on the search for new knowledge in three distinct but interrelated areas: the study of relationships between brain and behavior (physiological psychology), the study of perception and learning (general experimental psychology), and the study of origins of individual behavior and of the interaction among individuals in groups (developmental and social psychology). Accordingly, instruction in psychology on all levels (undergraduate, graduate, and postdoctoral) is organized to fall into these three areas which border on such diverse fields as biophysics, neurophysiology, philosophy, and sociology, as well as linguistics and other communication sciences.

Programs of research on these three principal themes (those of brain and behavior, perception and learning, and early development and social interaction) proceed in the Institute's Psychology Laboratories in close contact with the teaching program. The M.I.T. Psychology Building contains machine shops and electronic shops, a specialized research library, and facilities for brain research (electrophysiology, experimental surgery, and neurochemistry), for comparative studies of animal behavior, for observations on perception and memory in man in normal and abnormal states, and for the study of early stages in the acquisition, by children, of language, logic and social values.

UNDERGRADUATE SUBJECTS

Psychology subjects at the undergraduate level begin with INTRODUCTORY PSYCHOLOGY (9.00), which is the prerequisite for all of the subsequent undergraduate subjects. The remaining subjects fall into the three areas covered by the Department: physiological psychology, general experimental psychology, and social-developmental psychology. There is at present no undergraduate major in psychology at M.I.T., but undergraduate psychology subjects are open to all undergraduates as electives and can serve in fulfilling the undergraduate requirements for electives in the humanities and social sciences.



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M.I.T. ANNUAL CATALOGUES AND BULLETINS
1968/69

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GRADUATE STUDY IN PSYCHOLOGY (COURSE IX)

The program of studies leading to the degree of Doctor of Philosophy is designed to prepare graduate students for careers in teaching and research. No student will be admitted who does not expect to become a candidate for the Ph.D. degree. The program permits concentration in any one of the three areas already described: physiological psychology, general experimental psychology, and social-developmental psychology. Regardless of his area of concentration, each student is required to take, during his first two years in residence, the PROSEMINAR IN PSYCHOLOGY (9.001, 9.002) as well as four graduate seminars; two of these will be in the student's area of concentration and one in each of the other two fields within the Departmental Program. Throughout his graduate career, a student will be involved in research projects occupying at least one-half of his time, and aptitude will be assessed as much in the light of his demonstrated research abilities as in his performance in seminars or tutorials.

Ordinarily, incoming graduate students will have majored in psychology or related fields; however, promising candidates with other backgrounds are eligible. In place of the general requirements for admission given in Section 3 of this Catalogue, a student is expected to have the equivalent of one year of college-level work in three of the following four areas: physics, chemistry, biology, and mathematics. Minor deficiencies in this undergraduate preparation can be removed, with the permission of the Department, by taking the appropriate subjects at the Institute.

DOCTOR OF PHILOSOPHY

No stated number of graduate subjects in the Department of Psychology are required for the doctorate, but ordinarily the candidate will need two full academic years of work to prepare himself adequately for his general examinations and to meet 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 fulfill the language requirement as described in Section 3 of this Catalogue. The language or 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.



ALFRED P. SLOAN SCHOOL OF MANAGEMENT 7.

The Dean of M.I.T.'s Alfred P. Sloan School of Management describes its origins and present objectives.

The Alfred P. Sloan School of Management, founded at M.I.T. in 1952 as the School of Industrial Management, is the outgrowth of a pioneering curriculum combining management and engineering education which was first organized at the Institute in 1914. From that time, Course XV became the regular vehicle for providing this unique pattern of education to M.I.T.'s undergraduates. During this period many of M.I.T.'s most distinguished sons made their reputations as managers and business leaders. The gift of Alfred P. Sloan, Jr., in 1952, however, was the landmark in establishing a new level and a new scope in management education at M.I.T., and much of the story of management education at the Institute has been written since then. The Sloan School now offers an undergraduate Course leading to the degree of Bachelor of Science in Management; a two-year Master's Program leading to the degree of Master of Science in Management; a Doctoral Program leading to the degree of Doctor of Philosophy; a one-year Alfred P. Sloan Program in executive development; and a Program for Senior Executives, a nine-week executive development program for senior members of management.

In all its efforts, this School is committed to educating enterprise managers — men who have the will to manage and to risk, who can deal with complex systems, who have insight into themselves as well as others, who understand the total environment in which they live, and who continue to learn.

We seek to provide these men with a solid grounding in the academic disciplines relevant to management — economics, mathematics, and the behavioral sciences — and to develop their awareness of the multiple facets which characterize important management problems, from technical data to human factors. We want them to be able to reach decisions. At his best, our young graduate has the ability to move decisively and responsibly in an increasingly complex world. The opportunities for such men in a society full of challenge, both social and technical, are substantial and growing.

The education of men for management is our first purpose. But we are equally committed to the conduct of research to produce new understanding and better solutions to management problems, and we are engaged in communicating these results to an increasingly broader audience. Together, our research and education goals are mutually reinforcing, and we are confident of their continued impact on the fields of management and management education.

WILLIAM F. POUNDS

Management

SLOAN SCHOOL OF MANAGEMENT

WILLIAM FRANK POUNDS, PH.D.
Professor of Management; Dean

ABRAHAM J. SIEGEL, PH.D.
Professor of Industrial Relations; Associate Dean

PETER PAUL GIL, PH.D.
Associate Dean for Executive Programs; Senior Lecturer

SIDNEY STUART ALEXANDER, PH.D. (*Absent*)
Professor of Management

DOUGLASS VINCENT BROWN, PH.D.
Alfred P. Sloan Professor of Management

DONALD CARY CARROLL, PH.D. (*Absent*)
Professor of Management

JOHN FREDERICK COLLINS, PH.D., D.C.L.
Professor of Urban Affairs (Visiting)

PAUL HAROLD COOTNER, PH.D.
Professor of Finance

DAVID DURAND, PH.D.
Professor of Management

JAY WRIGHT FORRESTER, D.ENG.
Professor of Management

BILLY EARL GOETZ, PH.D.
Professor of Management

MASON HAIRE, PH.D.
Professor of Organizational Psychology and Management

THOMAS MASON HILL, A.B., M.B.A.
Professor of Management

DANIEL MARK HOLLAND, PH.D.
Professor of Finance

MORRIS A. HOROWITZ, PH.D.
Professor of Industrial Relations (Visiting)

EDWIN KUH, PH.D.
Professor of Finance

JOHN DUTTON CONANT LITTLE, PH.D. (*Absent*)
Professor of Management

DONALD GEORGE MARQUIS, PH.D.
Professor of Organizational Psychology and Management

FRANCO MODIGLIANI, D.JUR., D.SOC.SCI., LL.D.
Professor of Finance

LEO BENJAMIN MOORE, S.M.
Professor of Management

CHARLES ANDREW MYERS, PH.D.
Sloan Fellows Professor of Management

EDGAR HENRY SCHEIN, PH.D.
Professor of Organizational Psychology and Management; Undergraduate Planning Professor

CARROLL LOUIS WILSON, SC.D.
Professor of Management

ZENON SOTERIOU ZANNETOS, PH.D. (*Absent*)
Professor of Management

ARNOLD EVERETT AMSTUTZ, PH.D.
Associate Professor of Management

GORDON MAYER KAUFMAN, D.B.A.
Associate Professor of Management

MILES KENNEDY, PH.D.
Associate Professor of Management

PAUL WEBSTER MACAVOY, PH.D.
Associate Professor of Management

JOHN DANIEL NYHART, A.B., LL.B.
Associate Professor of Management

EDWARD BAER ROBERTS, PH.D.
Associate Professor of Management

ALVIN J. SILK, PH.D.
Associate Professor of Management

DAVID PETER TAYLOR, PH.D.
Associate Professor of Industrial Relations

LESTER CARL THUROW, PH.D.
Associate Professor of Management

LEON SELIGSBERGER WHITE, PH.D.
Associate Professor of Management

THOMAS JOHN ALLEN, JR., PH.D.
Assistant Professor of Organizational Psychology and Management

MICHAEL JAMES BROWER, PH.D.
Assistant Professor of Industrial History

WALLACE BRUCE STEWART CROWSTON, PH.D.
Assistant Professor of Management

GEORGE FRANKLIN FARRIS, PH.D.
Assistant Professor of Organizational Psychology and Management

JAY ROBERT GALBRAITH, D.B.A.
Assistant Professor of Management

GEORGE ANTHONY GORRY, JR., PH.D.
Assistant Professor of Management

MALCOLM MURRAY JONES, PH.D.
Assistant Professor of Management

DAVID ALLEN KOLB, PH.D.
Assistant Professor of Management

MILTON LAMPL LAVIN, PH.D.
Assistant Professor of Organizational Psychology and Management

LEON HERSCHEL LIEBMAN, PH.D.
Assistant Professor of Management

WILLIAM ARTHUR MARTIN, PH.D.
Assistant Professor of Management

DANIEL QUINN MILLS, PH.D.
Assistant Professor of Industrial Relations

DAVID BRUCE MONTGOMERY, PH.D.
Assistant Professor of Management

STEWART CLAY MYERS, PH.D.
Assistant Professor of Finance

DAVID NORMAN NESS, B.S.B.A.
Assistant Professor of Management

ALAN LEE PATZ, PH.D.
Assistant Professor of Organizational Psychology and Management

JOHN FRANKLIN PIERCE, JR., PH.D.
Assistant Professor of Management

GERALD ALBERT POGUE, PH.D.
Assistant Professor of Management

JOHN FRALICK ROCKART, PH.D.
Assistant Professor of Management

IRWIN MARTIN RUBIN, PH.D.
Assistant Professor of Organizational Psychology and Management

KENAN EYUP SAHIN, PH.D.
Assistant Professor of Management

MYRON S. SCHOLES, PH.D.
Assistant Professor of Finance

MICHAEL STEWART SCOTT MORTON, D.B.A.
Assistant Professor of Management

JEREMY FRANK SHAPIRO, PH.D.
Assistant Professor of Management

CHRISTOPHER REED SPRAGUE, PH.D.
Assistant Professor of Management

CARL VERNER SWANSON, S.B.
Assistant Professor of Management

GLEN LEE URBAN, PH.D.
Assistant Professor of Management

Administrative Officer

GERTRUDE ELIZABETH BURNS

Senior Lecturers

RICHARD BECKHARD, A.B.
GORDON FALK BLOOM, LL.B., PH.D.
HERBERT FRANKLIN GOODWIN, S.B.
JAMES BARNES HARTGERING, M.D.
STANLEY MARTIN JACKS, A.M., LL.B.
Advisor to Prelaw Students
WILLIAM LOUIS LETWIN, PH.D.
RICHARD STETSON MORSE, D.ENG., D.SC.
RICHARD DUNLOP ROBINSON, PH.D.

Lecturers

AVERY REMINGTON JOHNSON, PH.D.
RICHARD THOMAS MURPHY, JR., A.B., B.S., LL.B.
DAVID SIROTA, PH.D.

Instructors

THOMAS PATRICK GERRITY, JR., M.S.
ROBERT SHAW GREEN, M.S.E.E.
THOMAS IRVIN NELSON, M.S.
RICHARD LEE SCHMALENSEE, S.B.

Executive Development Programs

PRISCILLA ANN KARB, A.B.
Associate Director

Assistant for Graduate Programs

MIRIAM SHERBURNE, A.B.

Assistant for Undergraduate Programs

ESTHER MERRILL, B.S.

Senior Research Associate

HEINZ ERICH FRANZ-LUZNY, LL.D.

Research Associates

DAVID ANTHONY BUTTERFIELD, M.A.
ALEXANDER LE FEVRE PUGH, III, E.E.
WILLIAM DONALD PUTT, PH.D.
JON MAX SHEPARD, PH.D.

Professors Emeriti

EDWARD LINDLEY BOWLES, D.SC.
Professor of Industrial Management, Emeritus

EDWARD PENNELL BROOKS, D.S.C.
Professor of Industrial Management, Emeritus; Dean Emeritus

Management

SLOAN SCHOOL OF MANAGEMENT

THE UNDERGRADUATE CURRICULA

Management (Course XV)

The Alfred P. Sloan School of Management offers five undergraduate programs that provide bases for widely varying alternative management-related careers. The five curricula range from an opportunity for student initiative in the design of special management programs, to those providing skills in the understanding and managerial use of behavioral science and management science, to one that develops the broad outlook needed for general management practice. In most of the programs it is possible for a student who is admitted to graduate work to schedule his electives to permit receipt of the Bachelor of Science in Management degree at the end of four years of study and the Master of Science in Management degree at the conclusion of the fifth year.

Common to all of the curricula is the principle that each of the School's undergraduate students should gain an education in depth in an area of relevance and importance to the future manager. This education includes exposure to the underlying disciplines of management and to the general environment in which management operates. A sequence of four core subjects enables a common foundation to be built around an understanding of the organizational problems of the manager in coping with situations arising inside and outside of the firm, and develops a knowledge of the psychological and economic fundamentals of management. Beyond this management core each student has a number of alternative paths by which he is encouraged to learn something about management reasonably well, in contrast with being exposed to a large number of things but only superficially.

In addition to the flexibility inherent in the four curricula, and especially in the option for student initiative in Program 1, each program provides the further freedom of a number of unrestricted elective subjects. By different approaches to elective choice a variety of educational objectives might be served. Selection of subjects treating the functional areas of management should permit completion of both the Bachelor and Master of Science degrees in five years, as mentioned above. In-depth exposure to an area of physical science or engineering, in addition to an education in management, can be achieved by a technically oriented elective program. Appropriate selection of electives should permit a student to meet admission requirements of medical, law, or other graduate schools.

Each student arranges his program of studies with the advice and consent of a Faculty Counselor. To assist freshmen and sophomores further in choosing among the several alternative career paths, a senior faculty member of the Sloan School, designated the Undergraduate Planning Counselor, is available for discussions. Further information on any of the programs may also be obtained at the office of the Undergraduate Programs in Management, Room E52-472.

The curricula requirements are given below.

THE SPECIAL PROGRAM IN MANAGEMENT (PROGRAM 1)

The Special Program in Management has been designed to encourage student initiative in management education. Specific requirements are limited to General Institute Requirements and the four management core subjects. Beyond these any student (or group of students) may propose a coordinated program that he regards as meaningful to his own management-related career objectives. Each student-initiated professional program needs the approval of three faculty members (including at least two from the Sloan School of Management).

A proposed program should contain a specified series of subjects, planned and designated in advance of proposal submission, totaling between 54 and 82 Institute credit units. No more than one-third of these credits may be in Special Studies subjects. Not all of the individual subjects need be offered by the Sloan School of Management, but the program as a whole will be judged for its relevance and importance to management.

Programs 2, 3, 4 and 5 have been planned to meet the anticipated needs of most undergraduates interested in management. Program 1 is intended to cope with unanticipated student interests as well as with the special requirements of the highly motivated student. A senior faculty member of the Sloan School of Management has been designated Undergraduate Planning Counselor. He is available to freshmen and sophomores to discuss the appropriateness of Programs 2, 3, 4 and 5 to each student's career plans, and/or to assist students in designing new professional programs within the over-all framework of Program 1.

BEHAVIORAL SCIENCE IN MANAGEMENT PROGRAM (PROGRAM 2)

This program is designed to provide its graduate with the proper tools for the utilization of behavioral science theory and research knowledge in the managerial context.

The curriculum will pursue a spiral course exposing the student to the same basic behavioral science principles at several levels of complexity, and each time, from a somewhat different vantage. In following such a course, the student will develop the structure necessary for the accomplishment of a major learning experience, the research practicum, in his senior year. In other words, following an introductory survey in the MANAGERIAL PSYCHOLOGY "core" subject (15.06), each student will go through a second cycle of the spiral process as he studies behavioral science concepts and their interrelations in depth in two subjects, SOCIAL PSYCHOLOGY (15.32) and COMPLEX ORGANIZATIONS (15.33). In his senior year the student encounters the third cycle, that of an actual experience in searching for new knowledge and interpreting his findings.

This combination of theory, research and practical experience in behavioral science will enable an individual to pursue any one of a number of endeavors upon completion of the program.

MANAGEMENT SCIENCE PROGRAM (PROGRAM 3)

The Management Science Program caters to the mathematically inclined and problem solving undergraduate who has little interest in an engineering or science research career. The program is difficult and challenges even the superior student.

The Management Science Program permits the undergraduate to maintain maximum flexibility for career choice. A graduate knows enough to be immediately usefully employed in industry as a system analyst. He might take graduate training in business and thus broaden himself. Or he might choose to pursue his specialty at the graduate level in operations research, computer science, or applied mathematics. Thus, the program serves equally well for terminal or pregraduate training.

GENERAL MANAGEMENT PROGRAM (PROGRAM 4)

Program 4 is designed to meet the educational needs of the undergraduate who wants a broader background in the decision making, policy formulation and operating problems of the manager. The program builds upon the four required management core subjects with specified subjects that integrate psychological, economic, and environmental considerations in management. Further depth in any of these areas may be attained through appropriate elective choice.

The General Management Program will prepare the student for line management responsibilities in the generalist tradition. Administrative positions in the functional and staff fields would be the normal beginnings of career development through this program with the special advantage of a wide choice of areas. For the graduate of this program, the typical company will provide effective orientation activities as a valuable complement to his educational experience. Research administration, engineering and office management, and varied executive responsibilities in production, marketing and finance are examples of employment possibilities.

DYNAMICS OF MANAGEMENT SYSTEMS PROGRAM (PROGRAM 5)

The Dynamics of Management Systems Program focuses on the feedback structure of organizations. The unifying concepts of feedback processes are stressed to show how the same principles are encountered in management, economics, engineering, life processes, and the humanities.

The systems of interest to the manager are multi-loop, contain both positive and negative feedback, and are of high order and non-linear. To understand such systems they must be seen from as many perspectives as possible — as organized according to principles of structure; as laboratory observation using physical feedback processes; as descriptive subjects dealing with the structure and dynamics of social systems; as a mathematical interpretation relating structure and policy to growth and stability; as computer simulation of system models; and as field projects relating theory to practice.

This program uses feedback structure and dynamics to unify and interrelate the functional areas of management. The program is suitable for either the line manager or the systems analyst. It should serve as a foundation for graduate study or practice in a wide variety of fields.

GENERAL INSTITUTE REQUIREMENTS

					Total units
	Specific Science Subjects				
5.01	CHEMISTRY	5	0	7	
8.01	PHYSICS I	5	0	7	
8.02	PHYSICS II	5	0	7	
18.01	CALCULUS	4	0	8	
18.02	CALCULUS	4	0	8	
					60
	Humanities and Social Science Subjects[1]				**68**
	(see pages 50–55)				**128**

Management

SLOAN SCHOOL OF MANAGEMENT

GENERAL INSTITUTE REQUIREMENTS *(Continued)*

Science Distribution Requirement

At least 36 units in three fields (see pages 48–49)

Laboratory Requirement

At least 12 units (see page 49)

[1] The upperclass program in the humanities and social sciences is to be chosen in consultation with the student's Faculty Counselor.

1. SPECIAL PROGRAM IN MANAGEMENT CURRICULUM

GENERAL INSTITUTE REQUIREMENTS				*Total units*
Specific science and humanities and social science subjects (see above)				**128**
Science Distribution Requirements[1] (see page 48)				**36**
Laboratory Requirement[1] (see page 49)				**12**
DEPARTMENTAL PROGRAM				
Required Subjects				
15.05	INTRODUCTION TO MANAGEMENT	4	0 8	
15.06	MANAGERIAL PSYCHOLOGY	3	0 6	
15.07	MANAGERIAL ECONOMICS	4	0 8	
15.08	MANAGERIAL ENVIRONMENT	4	0 8	
				45
Restricted Electives[2]				
A coordinated program of professional electives relevant to management should be developed by the student, subject to faculty approval.				**54 to 82**
Unrestricted Electives[2]				**85 to 57**
Total units required for the S.B. degree				**360**

[1] One or two science distribution or laboratory subjects may be required as part of an approved professional program. See, for example, the specified curricula of the Behavioral Science, Management Science, General Management, and Dynamics of Management Programs.

[2] The student has the option of designing his own professional program of electives (subject to faculty approval) or of selecting one of the previously designated professional programs in Course XV. For examples of the latter option see the curricula of the Behavioral Science Program, the Management Science Program, the General Management Program, and the Dynamics of Management Program.

2. BEHAVIORAL SCIENCE IN MANAGEMENT PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS				*Total units*
Specific science and humanities and social science subjects (see above)				**128**
The Science Distribution Requirement will be satisfied by 1.00 and 18.10, which are required in the Departmental Program, plus appropriate subjects (see page 48) totaling				**12**
Laboratory Requirement (see page 49)				**12**
DEPARTMENTAL PROGRAM				
Required Subjects				
15.05	INTRODUCTION TO MANAGEMENT	4	0 8	
15.06	MANAGERIAL PSYCHOLOGY	3	0 6	
15.07	MANAGERIAL ECONOMICS	4	0 8	
15.08	MANAGERIAL ENVIRONMENT	4	0 8	
15.31	STATISTICS FOR BEHAVIORAL SCIENCE	3	0 6	
15.32	SOCIAL PSYCHOLOGY	3	0 6	
15.33	COMPLEX ORGANIZATIONS	3	0 6	
15.34	INTERPERSONAL DYNAMICS LABORATORY	0	3 3	
15.35	BEHAVIORAL SCIENCE RESEARCH METHODS	3	0 9	
15.36	BEHAVIORAL SCIENCE RESEARCH PRACTICUM	6	0 12	
1.00	INFORMATION SYSTEMS	3	3 6	
18.10	APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES	3	0 9	
				132
Restricted Electives				
A minimum of 27 units of additional engineering or science electives				**27**
Unrestricted Electives				**49**
Total units required for the S.B. degree				**360**

3. MANAGEMENT SCIENCE PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS				*Total units*
Specific science and humanities and social science subjects (see above)				**128**
The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, plus appropriate subjects[1] (see page 48) totaling				**24**
Laboratory Requirement (see page 49)				**12**
DEPARTMENTAL PROGRAM				
Required Subjects				
15.05	INTRODUCTION TO MANAGEMENT	4	0 8	
15.06	MANAGERIAL PSYCHOLOGY	3	0 6	
15.07	MANAGERIAL ECONOMICS	4	0 8	
15.08	MANAGERIAL ENVIRONMENT	4	0 8	
6.28	PROBABILISTIC SYSTEMS ANALYSIS	4	0 8	
15.10	QUANTITATIVE METHODS IN MANAGEMENT	3	0 6	
15.54	[2]MANAGEMENT INFORMATION TECHNOLOGY	3	0 6	
14.371	STATISTICAL THEORY	3	0 6	
15.56	MANAGEMENT SCIENCE FIELD STUDY	4	0 8	
15.094	STATISTICAL DECISION THEORY I	3	0 6	
18.034	DIFFERENTIAL EQUATIONS	3	0 9	
				117
Restricted Electives				
A minimum of 18 units are to be selected from the following list of electives:				
6.251	DIGITAL COMPUTER PROGRAMMING SYSTEMS	3	2 7	
6.253	THEORETICAL MODELS FOR COMPUTATION	3	0 9	
6.536	PROBABILISTIC MODELS IN SYSTEMS ENGINEERING AND OPERATIONS RESEARCH	3	0 9	
6.544J	HEURISTIC PROGRAMMING AND ARTIFICIAL INTELLIGENCE	3	0 9	
14.372	STATISTICAL THEORY	3	0 6	
15.58	INDUSTRIAL DYNAMICS	3	0 6	
15.591	MATHEMATICAL PROGRAMMING I	3	0 6	
15.592	MATHEMATICAL PROGRAMMING II	3	0 6	
15.593	STOCHASTIC SYSTEMS	3	0 6	
				18
Unrestricted Electives				**61**
Total units required for the S.B. degree				**360**

[1] 8.03T and 6.01, or 2.02 and another choice are suggested.

[2] 1.00 is an acceptable substitute for 15.54.

4. GENERAL MANAGEMENT PROGRAM CURRICULUM

GENERAL INSTITUTE REQUIREMENTS	*Total units*
Specific science and humanities and social science subjects (see above)	**128**
The Science Distribution Requirement will be satisfied by 1.00 and 18.10, which are required in the Departmental Program, plus appropriate subjects (see page 48) totaling	**12**
Laboratory Requirement (see page 49)	**12**

DEPARTMENTAL PROGRAM

	Required Subjects				
15.05	INTRODUCTION TO MANAGEMENT	4	0	8	
15.06	MANAGERIAL PSYCHOLOGY	3	0	6	
15.07	MANAGERIAL ECONOMICS	4	0	8	
15.08	MANAGERIAL ENVIRONMENT	4	0	8	
15.10	QUANTITATIVE METHODS IN MANAGEMENT	3	0	6	
15.34	INTERPERSONAL DYNAMICS LABORATORY	0	3	3	
15.38	ADMINISTRATIVE THEORY AND PRACTICE	3	0	6	
15.53	INTRODUCTION TO MANAGERIAL INFORMATION AND CONTROL SYSTEMS	3	0	6	
15.70	MANAGEMENT DECISIONS I	3	0	6	
15.71T	MANAGEMENT DECISIONS II	3	0	6	
15.73	MANAGEMENT LABORATORY	3	3	3	
1.00	INFORMATION SYSTEMS	3	3	6	
18.10	APPLICATIONS OF PROBABILITY AND RANDOM VARIABLES	3	0	9	
					129
	Restricted Electives				
	A minimum of 27 units of additional engineering or science electives.				**27**
	Unrestricted Electives				**52**
Total units required for the S.B. degree					**360**

5. DYNAMICS OF MANAGEMENT SYSTEMS CURRICULUM

	Total units
GENERAL INSTITUTE REQUIREMENTS	
Specific science and humanities and social science subjects (see page 187)	**128**
The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, and 2.02 or 6.01, which appear on the list of restricted electives, plus appropriate subjects (see page 48) totaling	**12**
The subject 15.571, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.	

DEPARTMENTAL PROGRAM

	Required Subjects				
15.05	INTRODUCTION TO MANAGEMENT	4	0	8	
15.06	MANAGERIAL PSYCHOLOGY	3	0	6	
15.07	MANAGERIAL ECONOMICS	4	0	8	
15.08	MANAGERIAL ENVIRONMENT	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
15.571	[1,2]FEEDBACK DYNAMICS LABORATORY	2	6	4	
15.572	PRINCIPLES OF SYSTEMS	3	0	6	
15.574	[2]SYSTEM MATHEMATICS	3	0	6	
15.576	INDUSTRIAL DYNAMICS I	3	0	6	
15.577	INDUSTRIAL DYNAMICS II	3	0	6	
15.578	RESEARCH SEMINAR IN DYNAMICS OF MANAGEMENT SYSTEMS I	3	0	6	
15.579	RESEARCH SEMINAR IN DYNAMICS OF MANAGEMENT SYSTEMS II	3	0	6	
					123
	Restricted Electives				
2.02	INTRODUCTION TO SYSTEM DYNAMICS	3	1	8	
	or				
6.01	INTRODUCTORY NETWORK THEORY	4	0	8	
	A coordinated study in one area of social systems as institutional and descriptive foundation for the Research Seminar, subject to approval of the Faculty Advisor.			12	
				27	
					39
	[1]***Unrestricted Electives***				**58**
Total units required for the S.B. degree					**360**

[1] If the student has already met the Institute undergraduate Laboratory Requirement, 15.571 can be replaced with an arranged 6-hour laboratory in feedback systems with registration under 15.95 or by an approved laboratory in another department.

[2] 6.213T or 2.14 can be substituted for 15.571 and 15.574.

[3] Schedules of students in Course XV, Program 5, may always be arranged to leave available 12 units of unrestricted elective in the second year.

GRADUATE STUDY IN MANAGEMENT

The Alfred P. Sloan School of Management offers graduate study leading to the degrees of Master of Science in Management and Doctor of Philosophy.

MASTER OF SCIENCE

The basic disciplines underlying sound management are the central theme of the Master's program, a two-year graduate program for young men who seek executive careers. This program gives students a grasp of fundamentals and techniques in management coupled with a breadth of view which prepares them for general management responsibility. Its emphasis on searching for and organizing an analytical framework on which later experience can build is a characteristic which sets this School apart.

The School welcomes applications from college graduates in all fields of concentration in which rigorous preparation is required. Graduates in the physical sciences, engineering, the liberal arts, and the social sciences are encouraged to apply if they meet the general entrance requirements specified below.

The typical Master's degree program in 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 terms or in one year. The required curriculum for those who have done no previous work in this field includes subjects in five general areas:

I. Mathematics for Management (15.091, 15.092)
II. Economics for Management (15.012, 15.014)
III. Human Factors in Management (15.312, 15.331)
IV. Information and Decision Systems (15.412, 15.501, 15.812)
V. Administrative Practices and Policies (15.201, 15.712)

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 subjects in addition to 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

Management

SLOAN SCHOOL OF MANAGEMENT

Catalogue. Selection is not limited to offerings in the Alfred P. Sloan School of 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 extensive facilities of the Institute's Information Processing Services Center as well as the School's own computation facilities are available for use in thesis and research work. The Master's thesis usually involves intensive study of a problem in industrial management or of problems in the management of other complex organizations. Such projects might include the management of education, health technologies, or public affairs. Part-time research assistantships also afford students opportunity for direct participation in faculty research.

DOCTOR OF PHILOSOPHY

The doctoral program in management is designed for students interested in teaching or other professional management careers. 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 somewhat more than three years' work, about two years of course work and another year for the doctoral thesis. The student who already holds the Master's degree can complete the doctorate in a shorter time. 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 language requirements specified in Section 3.

Distribution

A student must present evidence of his grasp of the subject areas required in M.I.T.'s program for the Master's degree in Management (see above). This evidence may be presented by M.I.T. graduate subject credit or by examination.

Specialization

The candidate must offer, subject to approval by his advisor, an area of specialization consisting of one applied area of management, two fields of a primary discipline and one other field which may be applied or in the same or another discipline.

Applied Fields	*Disciplines*
Managerial Information and Controls	*Economics*
Management Information Systems	*Macro economics*
Operations Management	*Micro economics*
Labor Economics and Labor Relations	*Behavioral Sciences*
Personnel Administration	*Social Psychology*
Finance	*Individual Psychology*
Marketing	*Sociology*
Industrial Dynamics	*Political Science and Law*
International Business	*Quantitative Studies*
Organization	*Applied Mathematics*
	Statistics
	Operations Research
	Computer Science

General Examination

Upon prospective completion of the program of course work arranged with his advisor, the student takes a general examination in the four fields of his choice as outlined above.

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 differential calculus; at least one year of an experimental science at the college level; and a subject in principles of economics. An undergraduate subject in elementary psychology is desirable. 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 Alfred P. Sloan School of Management, other than applicants for the Executive Development Programs (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 MANAGEMENT

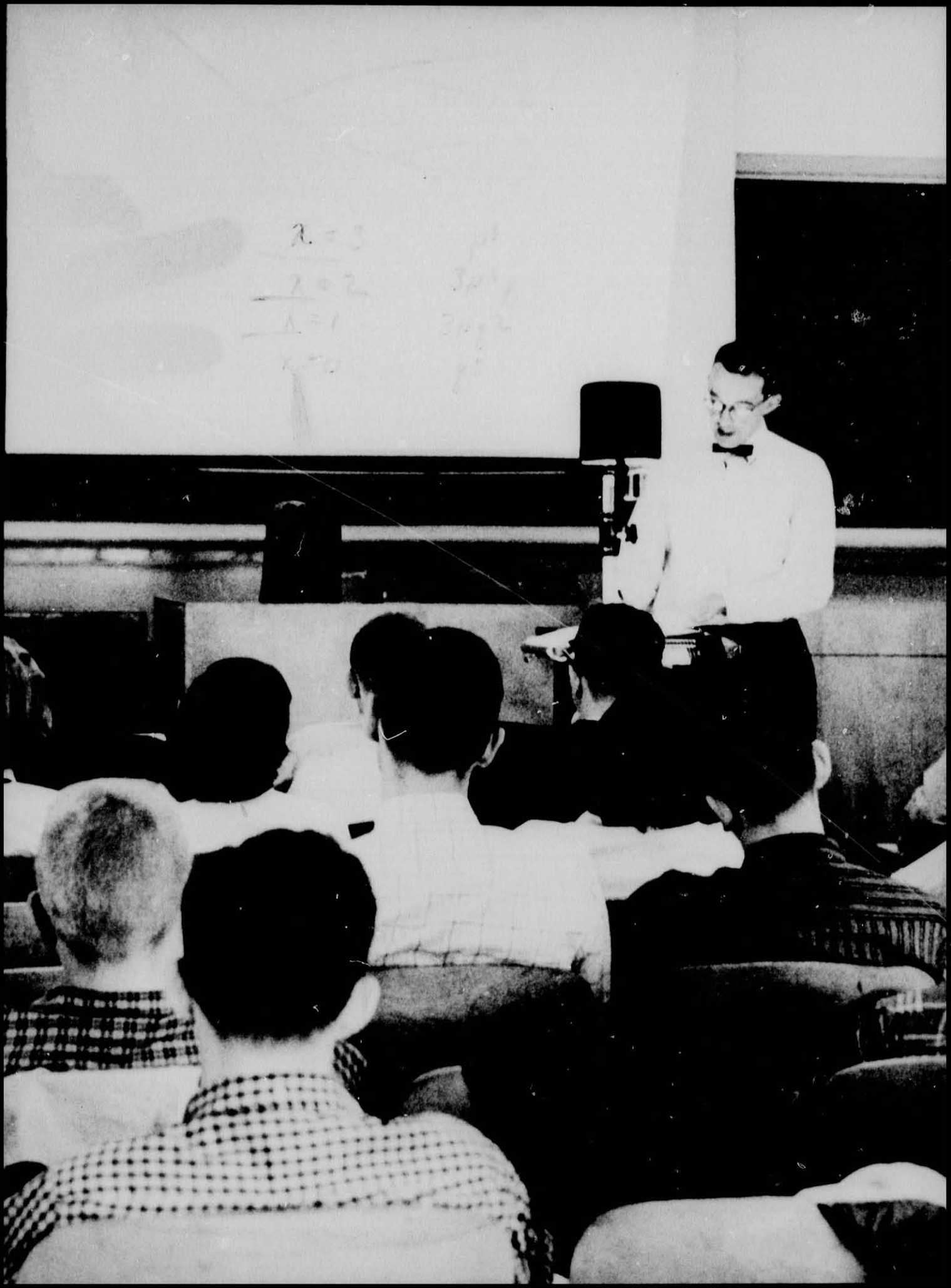
The Alfred P. Sloan School of Management provides two programs for business executives who wish to extend their knowledge of the fundamentals underlying effective management. Applicants for these programs are nominated by their companies and selected by M.I.T.

The *Alfred P. Sloan Program* enrolls exceptionally able young executives (32 to 38 years of age) who have demonstrated potential for filling positions of senior responsibility in the future. These young executives are sponsored by industry, government, and other organizations (or they may apply independently); a limited number of men are selected from abroad. The 12-month Program provides for regular classroom work plus intimate contact with business and government leaders here and abroad. It is taken in conjunction with the regular graduate program and may lead to the degree of Master of Science in Management. Approximately 45 men are admitted each year, and they are divided into two or three groups for most of their course work.

The *Program for Senior Executives* is an intensive nine-week course of study designed for the mature executive already in or preparing for a position of major managerial responsibility. Enrollment is limited to 25 qualified executives in each of the two nine-week sessions held in the spring and fall each year.

Participants reside at Endicott House in Dedham, where they enjoy the quiet and graceful environment of a private estate furnished tastefully and comfortably. The regular classroom work is conducted at the Sloan Building, 50 Memorial Drive.

Information about these programs may be obtained by writing to the Associate Dean for Executive Programs.



SCHOOL OF SCIENCE 8.

The role of science at M.I.T. is described by the Dean of the School.

Science is concerned with the understanding of the physical world, and the range of this search for understanding extends from the innermost events in the atomic nucleus to the farthest detectable reaches of the universe. Modern science has proved useful in many important ways, but the search for understanding is also carried out because man is curious about the world around him. Scientific research has become increasingly exciting because of the breadth and depth of understanding which is being achieved and the increasing integration of knowledge from different fields.

Science has of course contributed in the most fundamental way to the advancement of technology, and technology has contributed importantly to the advancement of science. At M.I.T. the relationships between science and technology are especially close and mutually reinforcing.

Training in science provides the basis for many types of careers. People with scientific training are needed for teaching and research, but scientific training provides an opportunity to enter other professions as well. Industry and government have increasing needs for scientists to carry out research as individuals or as members of a larger team attacking a problem requiring a multidisciplinary approach. People with scientific training are also needed for managerial positions in industry and government. Approximately 40 per cent of the professional employees of the Federal government are scientists and engineers.

The sciences may be broadly classified as earth and planetary sciences, life sciences, mathematics, and physical sciences. At M.I.T. instruction is provided in all of these fields at the undergraduate and graduate levels. Research is carried out in all of these fields by staff, graduate students, postdoctoral students, and also undergraduates.

The earth and planetary sciences are represented by oceanography, meteorology, geophysics and planetary physics, and geology-geochemistry. Instruction and research in these areas emphasize the application of the principles and techniques of fundamental scientific disciplines to understand our environment, and this tends to bring these fields together and emphasize their interdependence. In the study of oceanography there is active cooperation in research and teaching with the Woods Hole Oceanographic Institution.

The life sciences are in a period of rapid growth as a result of recent discoveries and the applications of techniques and ideas from chemistry and physics. At M.I.T. the areas of biology which receive special emphasis are cell biology and physiology, biochemistry, biophysics, microbiology, and nutrition and food science. Instruction and research in the life sciences cover the whole range from the properties of molecules of biological importance in-

cluding proteins, nucleic acids, enzymes and polysaccharides, the study of systems of biochemical reactions, the study of single cells, the study of the brain and nervous system, and finally the nutrition of man.

Mathematics is a field that is independent of the sciences but in its history it has received stimulation from the sciences and has greatly benefited them by providing a common language and powerful techniques. Instruction and research are provided in analysis, algebra, geometry, topology and many areas of applied mathematics. The latter field has involved collaborative work with many other disciplines at M.I.T.

The physical sciences are represented by chemistry and physics. Instruction and research in the Department of Chemistry include physical chemistry and chemical physics, organic chemistry, inorganic and nuclear chemistry, and analytical chemistry. In addition there are opportunities to cooperate with other departments in the application of chemistry to problems of biology, planetary and space science, material sciences and chemical engineering, for example. The field of chemistry has recently undergone major changes because of the introduction of more instrumental methods and theoretical techniques.

Physics has seen a remarkable development in this century as the result of the development of quantum mechanics and the theory of relativity. The identification of so many new particles in the last ten years has shown that much remains to be done before an understanding of the fundamental building blocks of the universe will be achieved. Research in the Department of Physics involves too great a variety of fields to mention them all, but some fields are particle and nuclear physics, quantum theory, spectroscopy, astrophysics, space physics, solid-state physics, masers, atomic beams, nuclear magnetic resonance, cosmic rays, plasma, low temperatures, magnetism, and accelerator physics.

The science programs at M.I.T. profit from the availability of laboratories of an interdepartmental nature which facilitate work in fields which cross the lines of traditional disciplines. Some of these facilities include the Cambridge Electron Accelerator (operated jointly by Harvard and M.I.T.), Center for Materials Science and Engineering, Center for Space Research, Information Processing Services Center, Laboratory for Nuclear Science, Lincoln Laboratory, National Magnet Laboratory, and Research Laboratory of Electronics. Through these laboratories and through personal contacts by members of the science departments within the Institute and outside, the sciences are brought to bear on problems of importance to the surrounding academic community, industry, and government. The School of Science provides the possibility of study and research in the most basic scientific and mathematical areas and also for the use of these ideas in a wide variety of applications.

ROBERT A. ALBERTY

ROBERT ARNOLD ALBERTY, PH.D., SC.D.
Dean

JOEL ORLEN, M.A.
Administrative Officer

SCIENCE COUNCIL

BORIS MAGASANIK, PH.D.
Head, Department of Biology

JOHN ROSS, PH.D.
Head, Department of Chemistry

FRANK PRESS, PH.D.
Head, Department of Geology and Geophysics

NORMAN LEVINSON, SC.D.
Head, Department of Mathematics

HENRY GARRETT HOUGHTON, SC.D.
Head, Department of Meteorology

NEVIN STEWART SCRIMSHAW, PH.D., M.D., D.P.S.
Head, Department of Nutrition and Food Science

VICTOR FREDERICK WEISSKOPF, PH.D., SC.D.
Head, Department of Physics

ALBERT GORDON HILL, PH.D.
Chairman, Physics Council

EXECUTIVE OFFICERS AND DEPUTY HEADS

GENE MONTE BROWN, PH.D.
Department of Biology

JOHN WITHERS IRVINE, JR., PH.D., SC.D.
Department of Chemistry

DANIEL BURRILL RAY
Department of Mathematics

SAMUEL ABRAHAM GOLDBLITH, PH.D.
Department of Nutrition and Food Science

GEORGE GRAHAM HARVEY, PH.D.
Department of Physics

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.

In addition to the programs leading to the degree of Bachelor of Science in a designated field, as indicated under the appropriate departments, the School of Science also offers a program in the Physical Sciences (Course XII-B) leading to the degree of Bachelor of Science without designation of field.

This program is explained in detail under the Department of Geology and Geophysics. See page 206 for further details.

Each student arranges his program of studies with a Faculty Counselor. Typical Course schedules are issued each term by the Registrar with the Class Schedules. R.O.T.C. subjects may be used according to the specifications in Section 2.

GENERAL INSTITUTE REQUIREMENTS

					Total units
Specific Science Subjects					
5.01	CHEMISTRY	5	0	7	
8.01	PHYSICS I	5	0	7	
8.02	PHYSICS II	5	0	7	
18.01	CALCULUS	4	0	8	
18.02	CALCULUS	4	0	8	
					60
Humanities and Social Science Subjects *(see pages 50–55)*					**68**
					128

Science Distribution Requirement
At least 36 units in three fields *(see page 48)*

Laboratory Requirement
At least 12 units *(see page 49)*

Department of Biology

BORIS MAGASANIK, PH.D.
Professor of Microbiology; Head of the Department
GENE MONTE BROWN, PH.D.
Professor of Biochemistry; Executive Officer
EUGENE BELL, PH.D.
Professor of Biology
JOHN MACHLIN BUCHANAN, PH.D., D.SC.
John and Dorothy Wilson Professor of Biochemistry
MAURICE SANFORD FOX, PH.D. (*Absent*)
Professor of Genetics
PAUL RANDOLPH GROSS, PH.D.
Professor of Biology
CECIL EDWIN HALL, PH.D.
Professor of Biophysics
VERNON MARTIN INGRAM, PH.D., D.SC.
Professor of Biochemistry
JEROME YSRAEL LETTVIN, M.D.
Professor of Communications Physiology
SALVADOR EDWARD LURIA, M.D., D.SC.
Sedgwick Professor of Biology
ALEXANDER RICH, M.D.
Professor of Biophysics
PHILLIPS WESLEY ROBBINS, PH.D.
Professor of Biochemistry
FRANCIS OTTO SCHMITT, PH.D., SC.D.
Institute Professor; Professor of Biology
IRWIN WHITING SIZER, PH.D.
Professor of Biochemistry; Dean of the Graduate School
DAVID FLOYD WAUGH, PH.D.
Professor of Biophysics
CORRADO BAGLIONI, M.D.
Associate Professor of Biology
DAVID BALTIMORE, PH.D.
Associate Professor of Biology
JOEL EDWARD BROWN, PH.D.
Associate Professor of Physiology
BERNARD SIDNEY GOULD, PH.D.
Associate Professor of Biochemistry
CHARLES EDWARD HOLT, III, PH.D.
Associate Professor of Biology
KURT SIEGFRIED LION, DR.ING.
Associate Professor of Applied Biophysics
SHELDON PENMAN, PH.D.
Associate Professor of Biophysics
ETHAN ROY SIGNER, PH.D.
Associate Professor of Microbiology
HARVEY FRANKLIN LODISH, PH.D.
Assistant Professor of Biology
PAUL REINHARD SCHIMMEL, PH.D.
Assistant Professor of Biochemistry
LISA AMELIA STEINER, M.D.
Assistant Professor of Biochemistry
KENNETH BOIVIN TAYLOR, M.D., PH.D.
Assistant Professor of Biochemistry

Administrative Officer

EDWARD JOSEPH GAUDIANO

Instructors

DAVID BOTSTEIN, PH.D.
ELIZABETH WINIFRED JONES, PH.D.
JOHN CHUNG LEE, PH.D.

Research Associates

AGNES JOYCE ALLISON, PH.D.
ANTHONY NOEL BARRETT, PH.D.
CHRISTOPHER DAVID BARRY, PH.D.
DWIGHT JOE BAUGHMAN, M.D., PH.D.
ANNAMARIA TORRIANI GORINI, PH.D.
JEREMY HAYWARD, PH.D.
SUNG HOU KIM, PH.D.
KARL KORNACKER, PH.D.
ERNST ADOLPH KUECHLER, PH.D.
BERTHA KALIFON MADRAS, PH.D.
GEORGE MARINOS MANIATIS, M.D.
JOSEPH PETER MASCARENHAS, PH.D.
ARLAND EUGENE OLESON, PH.D.
JAAKKO PERTTI PISPA, MED.SCI.D.
HELEN RUTH REVEL, PH.D.
DAVID HILTON ROSCOE, PH.D.
VIRGINIA FRANKLIN ROSS, PH.D.
ANNA RUFFILLI, D.B.SC.
DUANE DAVID SCHROEDER, PH.D.
VICTOR EZRA SHASHOUA, PH.D.
CHARLES WILBUR SLATTERY, PH.D.
LARY STAVY, PH.D.
RUTH STAVY, PH.D.
WERNER KARL STEUERNAGEL, E.E.
BERT LESTER VALLEE, M.D.
CESARE VESCO, M.D.
DONALD HERMAN VOET, PH.D.
WALTER ALAN WOLF, PH.D.
JAMES FERDINAND ZISSLER, PH.D.

Professor Emeritus

CLAIR ELSMERE TURNER, DR.PH., SC.D.
Professor of Public Health, Emeritus

BIOLOGY

The field of biology has undergone an impressive development during the last 25 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.

NUTRITION AND FOOD SCIENCE

The undergraduate curricula in Life Sciences also prepare students for careers in nutrition and food science and for graduate study in these fields. Students choosing specialization in this area should elect Program 3 and consult with the Department of Nutrition and Food Science before registration.

THE UNDERGRADUATE CURRICULUM

Life Sciences (Course VII)

The undergraduate curriculum in the Life Sciences is designed to prepare students for teaching and research careers in biology, nutrition, and food science; for graduate study, and for work in industries which are concerned with biological materials and fermentation processes. The Life Sciences curriculum also prepares students for graduate study in physiological psychology. Special emphasis is placed on preparing students for medical school, and this program is strengthened by the presence of 20 or more medical doctors who have come to the Department for special postdoctoral studies and research. Students find that the program is an excellent preparation for medical school and medical research.

The Life Sciences curricula stress a physical and chemical approach which includes the application of quantitative, analytical methods to various aspects of the life sciences; hence particular emphasis is given to those fields which, in the present stage of development, are susceptible of such treatment. As modern medicine becomes less empirical and more scientific, it is increasingly important that those who wish to prepare for medical research become acquainted with the quantitative approach of the physical sciences to biological phenomena. In Life Sciences Program 1 the student ordinarily takes general biology and organic chemistry in his second year; biochemistry, microbiology, physical chemistry, and genetics in his third year; and developmental biology and physiology in the fourth year.

A Life Sciences program with a greater degree of specialization in biophysics is also offered as Program 2. This program substitutes certain subjects in the physical sciences for some of the advanced subjects in the life sciences.

A Life Sciences program with specialization in nutrition and food science is offered as Program 3. Subjects in nutrition and food science are substituted for some advanced subjects in biology.

Undergraduate Specialization

The curricula in Life Sciences provide ample time for electives. Most students taking one of these curricula are preparing to go on to graduate work, and different electives are recommended depending upon the ultimate field of graduate specialization. Students interested in one of the following fields should consult the Department of Biology prior to registration: cell biology, physiology, biochemistry, biophysics, medicine, and microbiology.

All programs of the Course lead to the degree of Bachelor of Science in Life Sciences.

PROGRAM 1. LIFE SCIENCES CURRICULUM — *Total units*

GENERAL INSTITUTE REQUIREMENTS (*see page 195*)

Specific science and humanities and social science subjects — **128**

The subjects 5.41, 7.01, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.

Laboratory Requirement — **12**

The subject 7.02, which is among the Restricted Electives, appears on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.[1]

DEPARTMENTAL PROGRAM

Required Subjects

5.41	ORGANIC CHEMISTRY I	4	0	8
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION	2	8	2

(*continued*)

	***Required Subjects** (continued)*				
5.60	CHEMICAL THERMODYNAMICS	4	0	8	
7.01	GENERAL BIOLOGY	4	0	8	
7.05	GENERAL BIOCHEMISTRY	4	0	6	
7.051	GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
7.21	GENERAL MICROBIOLOGY	3	0	6	
7.03	GENETICS	3	0	6	
7.04	DEVELOPMENTAL BIOLOGY	2	0	4	
7.06	GENERAL PHYSIOLOGY	3	0	6	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					111
	Restricted Electives				
	Two of the following subjects:				
7.02	[1]GENERAL BIOLOGY LABORATORY	1	8	3	
7.031	GENETICS AND MICROBIOLOGY LABORATORY	1	6	2	
7.041	CELL BIOLOGY LABORATORY	1	6	2	
	One of the following subjects:				
8.03T	PHYSICS III	5	0	7	
1.00	INFORMATION SYSTEMS	3	3	6	
6.01	INTRODUCTORY NETWORK THEORY I	4	0	8	
	One of the following subjects:				
5.62	PHYSICAL CHEMISTRY	4	0	8	
5.63	PHYSICAL CHEMISTRY	4	0	8	
					42 or **45**
	***Unrestricted Electives**[2]*				**67** or **64**
Total units required for the S.B. degree					**360**

[1] If 7.02 is taken as fulfilling the Institute Laboratory Requirement, the total units of Restricted Electives will be 33 and the total of Unrestricted Electives will be 76.

[2] Schedules of students in Course VII, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the second year. A thesis is recommended but not required.

PROGRAM 2. SPECIALIZED BIOPHYSICS CURRICULUM

	Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 195*)	
Specific science and humanities and social science subjects	**128**
The subjects 5.41, 7.01, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.	
Laboratory Requirement	**12**
The subject 7.02, which is among the Restricted Electives, appears on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.[1]	

DEPARTMENTAL PROGRAM

	Required Subjects				
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION	2	8	2	
5.41	ORGANIC CHEMISTRY I	4	0	8	
5.60	CHEMICAL THERMODYNAMICS	4	0	8	
7.01	GENERAL BIOLOGY	4	0	8	
7.05	GENERAL BIOCHEMISTRY	4	0	6	
7.051	GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
8.03T	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
8.05	PHYSICS OF ATOMS AND MOLECULES	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
					114
	Restricted Electives				
	Biology — a minimum of 30 units, including two laboratory subjects, must be chosen from:				
7.02	[1]GENERAL BIOLOGY LABORATORY	1	8	3	
7.03	GENETICS	3	0	6	
7.031	GENETICS AND MICROBIOLOGY LABORATORY	1	6	2	
7.04	DEVELOPMENTAL BIOLOGY	2	0	4	
7.041	CELL BIOLOGY LABORATORY	1	6	2	
7.06	GENERAL PHYSIOLOGY	3	0	6	
7.21	GENERAL MICROBIOLOGY	3	0	6	
	Chemical Physics — at least 24 units must be chosen from:				
5.62	PHYSICAL CHEMISTRY	4	0	8	
5.63	PHYSICAL CHEMISTRY	4	0	8	
8.06	THEORETICAL PHYSICS I	4	0	8	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
					54
	***Unrestricted Electives**[2]*				**52**
Total units required for the S.B. degree					**360**

[1] If 7.02 is taken as fulfilling the Institute Laboratory Requirement, the total units of Restricted Electives will be 42 and the Unrestricted Electives will be 64.

[2] Schedules of students in Course VII, Program 2, may always be arranged to leave available 12 units of unrestricted elective in the second year. A thesis is recommended, but not required.

PROGRAM 3. NUTRITION AND FOOD SCIENCE CURRICULUM (See DEPARTMENT OF NUTRITION AND FOOD SCIENCE, page 218.)

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 or Doctor of Science. Study may be pursued in the following fields of specialization; cell 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 upon each student's active participation in research work.

Research facilities are available for a wide variety of fields in analytical biology, biochemistry, biophysics, and microbiology.

CELL BIOLOGY AND PHYSIOLOGY

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 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 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; molecular genetics; communications biophysics; and instrumentation for use in biology and medicine.

The cooperative arrangement with Harvard University is described in Section 3 of this Catalogue.

MICROBIOLOGY

The general properties of microorganisms are stressed, with special emphasis on microbial genetics and 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 two foreign languages or comprehensive knowledge of one foreign language is required for a Doctorate.

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 cell biology, microbiology, physiology, biochemistry, and biophysics. Information is available from the Head of the Department.

Department of Chemistry

JOHN ROSS, PH.D.
Professor of Chemistry; Head of the Department

JOHN WITHERS IRVINE, JR., PH.D., SC.D.
Professor of Chemistry; Executive Officer

ROBERT ARNOLD ALBERTY, PH.D., SC.D.
Professor of Chemistry; Dean of the School of Science

ISADORE AMDUR, PH.D.
Professor of Physical Chemistry

KLAUS BIEMANN, PH.D.
Professor of Chemistry

GEORGE HERMANN BÜCHI, D.SC.
Professor of Chemistry

CHARLES DUBOIS CORYELL, PH.D.
Professor of Chemistry

FRANK ALBERT COTTON, PH.D., SC.D.
Professor of Chemistry

EDMUND LEE GAMBLE, PH.D. (*Absent*)
Professor of Inorganic Chemistry

CARL WESLEY GARLAND, PH.D.
Professor of Chemistry

FREDERICK DAVIS GREENE, II, PH.D.
Professor of Chemistry

RICHARD HADLEY HOLM, PH.D.
Professor of Chemistry

HERBERT OTIS HOUSE, PH.D.
Professor of Chemistry

DAVID NEWTON HUME, PH.D.
Professor of Chemistry

RICHARD COLLINS LORD, PH.D., SC.D.
Professor of Chemistry; Director of the Spectroscopy Laboratory

IRWIN OPPENHEIM, PH.D.
Professor of Chemistry

DIETMAR SEYFERTH, PH.D.
Professor of Chemistry

JOHN CLARK SHEEHAN, PH.D., SC.D.
Professor of Organic Chemistry

DAVID POWELL SHOEMAKER, PH.D.
Professor of Chemistry

CLARK CONKLING STEPHENSON, PH.D.
Professor of Chemistry

CHARLES GARDNER SWAIN, PH.D.
Professor of Chemistry

JOHN STEWART WAUGH, PH.D.
Professor of Chemistry

GLENN ALLEN BERCHTOLD, PH.D.
Associate Professor of Chemistry

ALAN DAVISON, PH.D.
Associate Professor of Chemistry

GLEN EVERETT GORDON, PH.D.
Associate Professor of Chemistry

LAWRENCE JOSEPH HEIDT, PH.D.
Associate Professor of Physical Chemistry

DAVID MICHAEL HERCULES, PH.D.
Associate Professor of Chemistry

JAMES LLOYD KINSEY, PH.D.
Associate Professor of Chemistry

WILLIAM ROBERT MOORE, PH.D.
Associate Professor of Chemistry

GEORGE MCCLELLAND WHITESIDES, PH.D.
Associate Professor of Chemistry

KERRY WOLLING BOWERS, PH.D.
Assistant Professor of Chemistry

DAVID MAYER CHIPMAN, PH.D.
Assistant Professor of Chemistry

JAMES WILLIAM DUBRIN, PH.D.
Assistant Professor of Chemistry

THAYER CARLTON FRENCH, PH.D.
Assistant Professor of Chemistry

DANIEL SCHAEFFER KEMP, PH.D.
Assistant Professor of Chemistry

JOHN SIMPSON LEWIS, PH.D.
Assistant Professor of Chemistry and Geochemistry

PAUL REINHARD SCHIMMEL, PH.D.
Assistant Professor of Chemistry and Biology

ROBERT JAMES SILBEY, PH.D.
Assistant Professor of Chemistry

JEFFREY IRWIN STEINFELD, PH.D.
Assistant Professor of Chemistry

WILLIAM BEN WALTERS, PH.D.
Assistant Professor of Chemistry

Administrative Officer

EARLE ARTHUR GOODRICH, M.B.A.

Lecturer

DANIEL DOMINICK TRAFICANTE, PH.D.

Professors Emeriti

AVERY ALLEN ASHDOWN, PH.D.
Associate Professor of Organic Chemistry, Emeritus

JAMES ALEXANDER BEATTIE, PH.D.
Professor of Physical Chemistry, Emeritus

LEICESTER FORSYTH HAMILTON, S.B.
Professor of Analytical Chemistry, Emeritus

LOUIS HARRIS, PH.D.
Associate Professor of Physical Chemistry, Emeritus

FREDERICK GEORGE KEYES, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus

NICHOLAS ATHANASIUS MILAS, PH.D., D.SC.
Associate Professor of Organic Chemistry, Emeritus

EARL BOWMAN MILLARD, PH.D.
Professor of Physical Chemistry, Emeritus

AVERY ADRIAN MORTON, PH.D.
Professor of Organic Chemistry, Emeritus

GEORGE SCATCHARD, PH.D., SC.D.
Professor of Physical Chemistry, Emeritus

STEPHEN GERSHOM SIMPSON, PH.D.
Associate Professor of Analytical Chemistry, Emeritus

CHARLES MONTGOMERY WAREHAM, S.B.
Associate Professor of Inorganic Chemistry, Emeritus

RALPH CHILLINGWORTH YOUNG, PH.D.
Associate Professor of Inorganic Chemistry, Emeritus

CHEMISTRY

The Department of Chemistry offers an undergraduate program sufficiently flexible in its electives to provide excellent preparation for careers in many different areas of chemistry. The Department offers graduate programs leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science. There is a wide variety of opportunities for study and research in analytical, biophysical, geological, inorganic, nuclear, organic, and physical chemistry and in chemical physics.

THE UNDERGRADUATE CURRICULUM

Chemistry (Course V)

The Course is designed 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 chemistry, supplemented by instruction in mathematics and physics and in the humanities and other non-professional subjects.

Elective time allows each student to extend his knowledge in areas of special interest. Students intending to take graduate work may elect subjects which may give them more detailed knowledge in the areas in which they will pursue their graduate training. 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 and other non-professional areas.

The Course aims to stimulate and develop the research attitude, and the curriculum may include a thesis in the fourth year, or earlier, to give the student an opportunity to demonstrate his aptitude for creative effort.

The curriculum is carefully planned with a minimum amount of required basic material in chemistry and related fields, and there is ample opportunity for students to make a choice of electives from a large number of advanced chemistry and related subjects. Thus each student is given a general background in chemistry with opportunity for detailed study in specific areas. The Course leads to the degree of Bachelor of Science in Chemistry. The curriculum requirements for the degree are given below.

GENERAL INSTITUTE REQUIREMENTS (*see page 195*)

	Total units
Specific science and humanities and social science subjects	**128**
The Science Distribution Requirement will be satisfied by 5.41 or 5.60, which are required in the Departmental Program, plus appropriate subjects (see page 48) totaling	**24**
The subject 5.31, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.	

DEPARTMENTAL PROGRAM

	Required Subjects				
5.41	ORGANIC CHEMISTRY I	4	0	8	
5.31	INTRODUCTION TO CHEMICAL EXPERIMENTATION	2	8	2	
5.42	ORGANIC CHEMISTRY II	4	0	8	
5.32	INTERMEDIATE CHEMICAL EXPERIMENTATION	2	8	2	
5.60	CHEMICAL THERMODYNAMICS	4	0	8	
5.33	ADVANCED CHEMICAL EXPERIMENTATION	2	12	4	
5.62	PHYSICAL CHEMISTRY	4	0	8	
5.63	PHYSICAL CHEMISTRY	4	0	8	
5.03	PRINCIPLES OF INORGANIC CHEMISTRY I	3	0	9	
					114
	Unrestricted Electives[1]				**94**
Total units required for the S.B. degree					**360**

[1] The student's Faculty Counselor can offer suggestions for elective subjects, which are offered by this Department and by other departments, that will be of value in preparation for specialization in the various broad areas of chemistry. The proper choice of electives is particularly important for students planning to continue their education in a graduate school.

Students planning to take 5.89, particularly if they expect to prepare an undergraduate thesis during their fourth year, should indicate this intent to their Faculty Counselor as early as possible and not later than the beginning of their third year in order to arrange their subjects properly so as to have an adequate background in their area of specialization.

GRADUATE STUDY IN CHEMISTRY

The 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 areas of chemistry. In addition to studying formal subjects, each student undertakes a research problem which forms the core of his graduate work. Through the experience of conducting an investigation leading to a doctoral or Master's thesis, the student learns general research attitudes and methods of approach, and acquires training in some of the specialized techniques of research.

Attainment of the Master's degree is not prerequisite to a program of study leading to a doctorate. Indeed, new graduate students should register as doctoral candidates from the beginning of their graduate work. Applications for admission as a S.M. candidate are not accepted unless there is some special reason to seek a Master's degree as a terminal degree.

All graduate students are encouraged to select a research supervisor during the first term of residence. The research supervisor will serve as the student's advisor during the balance of his graduate career. In particular, the final program of graduate subjects will be established by the student and his research supervisor. In planning this program and in establishing a thesis problem, careful consideration will be given to the candidate's previous academic record and professional experience as well as his long-range aims and objectives.

The areas of research in the Department are organic, inorganic, physical, analytical, nuclear, geological, and biophysical chemistry, and chemical physics. A student's thesis research frequently will involve more than one of these fields.

Some of the research activities of the Department are carried out in association with the work of various interdisciplinary laboratories, such as the Center for Materials Science and Engineering, the Research Laboratory of Electronics, the Laboratory for Nuclear Science, and the Spectroscopy Laboratory. These interdepartmental research laboratories provide a stimulating interaction among the research programs of several M.I.T. departments and give students the opportunity to become familiar with research work in disciplines other than chemistry. There is also an opportunity for research in cooperation with other departments, such as Biology, Geology and Geophysics, and Physics.

Detailed information on the research activities of the faculty can be found in the *Directory of Graduate Research* published by the American Chemical Society.

Entrance Requirements for Graduate Study

The general requirements for admission to the Graduate School are set forth in Section 3 of this Catalogue. In particular, a student intending to pursue graduate work in chemistry should have as a background the equivalent of a good undergraduate program in chemistry. The Depart-

ment is flexible in its attitude toward the specific mathematics and physics preparation mentioned in Section 3; the essential requirement is demonstration of ability to progress with advanced study and research in some area of special interest. Mathematics and physics at least equivalent to the content of those subjects listed in Section 3 are important prerequisites for graduate work in physical chemistry or chemical physics. On the other hand, less preparation in mathematics and physics would be required for work in organic chemistry.

Graduate Record Examinations. Applicants for graduate admission to this Department are not required to submit G.R.E. scores. However, it is requested that scores be submitted by those persons who are taking the Graduate Record Examination.

The Graduate Degrees

The general requirements for graduate degrees are set forth in Section 3 of this Catalogue. Additional details relevant to Chemistry are given below.

MASTER OF SCIENCE IN CHEMISTRY

Candidates for the S.M. degree in Chemistry must demonstrate to the Department of Modern Languages and Linguistics an ability to read scientific literature in German, French, or Russian.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE

The Department does not have any formal subject requirements for doctoral degree. Each student, with the advice of his research supervisor, will pursue an individual program of study which is pertinent to his long-range research interests.

Foreign language requirement. Doctoral candidates may fulfill the Institute language requirement (see Section 3 of this Catalogue) with French, German or Russian. With the prior written consent of the student's research supervisor, examinations may also be arranged in other languages. In such cases, the special languages must be ones in which there is a significant literature in the field of the student's research specialization.

Major examinations. Written major examinations are cumulative, and a series of examinations is given each term. Separate examinations in physical, organic and inorganic chemistry are offered each time, and additional examinations in nuclear, analytical, biophysical chemistry or other specialized areas are also offered several times during the year. The level of these examinations will correspond to introductory graduate subjects, but they are not based specifically on such subjects. Considerable emphasis is placed on seminars and current literature. Six of these cumulative examinations must be passed to complete the written major examination. No fixed time limit is set for completion of this requirement, but progress will be reviewed periodically.

No other general written examinations are required. In particular, no qualifying (or "entrance") examinations are given. An assessment of each new student's background and a decision on the proper level of first-term graduate work is made on the basis of individual interviews.

A comprehensive oral examination in the candidate's major field of advanced study is held near the end of the third term of residence. Progress in research is examined at that time.

A final oral presentation of the subject of the doctoral research is scheduled after the thesis has been submitted and tentatively evaluated by a committee of examiners.

Assistantships

The Department appoints a number of degree candidates as teaching assistants who are usually assigned to laboratory subjects in the Department or to discussion sections of lecture subjects. It is customary to offer continued financial support to students who maintain a satisfactory record. Many students receive appointments to research assistantships after their first year, although departmental fellowships and reappointments to teaching assistantships are also available.

Inquiries about the graduate program or concerning appointments should be addressed to the Chairman of the Department Committee on Graduate Students, Chemistry Graduate Office, Room 2-331.

Department of Geology and Geophysics

FRANK PRESS, PH.D.
Professor of Geophysics; Head of the Department

KEIITI AKI, PH.D.
Professor of Geophysics

WILLIAM FRANCIS BRACE, PH.D.
Professor of Geology

MARTIN JULIAN BUERGER, PH.D.
Institute Professor, Emeritus; Professor of Mineralogy and Crystallography, Emeritus

HAROLD WILLIAMS FAIRBAIRN, PH.D.
Professor of Geology

PATRICK MASON HURLEY, PH.D.
Professor of Geology

THEODORE RICHARD MADDEN, PH.D.
Professor of Geophysics

IRWIN IRA SHAPIRO, PH.D.
Professor of Geophysics and Physics

ROBERT RAKES SHROCK, PH.D.
Professor of Geology

GENE SIMMONS, PH.D.
Professor of Geophysics

WILLIAM STELLING VON ARX, SC.D.
Professor of Physical Oceanography

WILLIAM HAMET PINSON, JR., PH.D.
Associate Professor of Geology

MEHMET NAFI TOKSÖZ, PH.D.
Associate Professor of Geophysics

DAVID ROBERT WONES, PH.D.
Associate Professor of Geology

SHAWN BIEHLER, PH.D.
Assistant Professor of Geophysics

FREDERICK AUGUST FREY, PH.D.
Assistant Professor of Geochemistry

JOHN SIMPSON LEWIS, PH.D.
Assistant Professor of Geochemistry and Chemistry

THOMAS B. McCORD, PH.D.
Assistant Professor of Planetary Physics

RICHARD STEVENS NAYLOR, PH.D.
Assistant Professor of Geology

JOHN BRELSFORD SOUTHARD, PH.D.
Assistant Professor of Geology

CARL ISAAC WUNSCH, PH.D.
Assistant Professor of Oceanography

Administrative Assistant

HENRY ADAMS MORSS, JR., PH.D.

Research Associates

DAE-HYUN CHUNG, PH.D.
GIORGIO FIOCCO, DR.ING.
DONALD V. HELMBERGER, PH.D.
TOMOWO HIRASAWA, D.SC.
KI-ITI HORAI, SC.D.
JOHN W. MINEAR, PH.D.
WILLIAM FREDERICK SIMMONS, PH.D.
JOSEPH BROUGHTON WALSH, PH.D.
RALPH AMBROSE WIGGINS, PH.D.
CHARLES GODDARD WING, PH.D.

Professors Emeriti

MARTIN JULIAN BUERGER, PH.D.
Institute Professor, Emeritus; Professor of Mineralogy and Crystallography, Emeritus

ROLAND DANE PARKS, E.M., M.S.
Associate Professor of Mineral Industry, Emeritus

WALTER LUCIUS WHITEHEAD, PH.D., D.SC.
Associate Professor of Geology, Emeritus

GEOLOGY AND GEOPHYSICS

The scope of geology and geophysics at M.I.T. includes the broad field of the evolution of the main planetary features; the composition, structure, and state of the atmospheres, oceans, surfaces, and interiors of planets; and the nature of the interplanetary medium. These problems are attacked by *in situ* physical measurements where possible, by laboratory studies on samples or models, and by theoretical-numerical studies influenced by the available data. No single department can fully cover all aspects of this broad subject. Chosen for special emphasis at M.I.T. are the fields of mineralogy-crystallography, experimental petrology, rock mechanics, regional geology and geophysics, geochemistry, seismology, planetary magnetism and electricity, heat flow, high pressure geophysics, geophysical fluid dynamics, particles in planetary fields, physical and chemical oceanography, and marine geology and geophysics. Experimental facilities are available for training and research in these fields in the Department, in M.I.T. laboratories such as the Center for Space Research and Lincoln Laboratory, and in cooperating institutions such as the Woods Hole Oceanographic Institution. To summarize in more conventional terms, the Department is concerned with a program of education and research in modern aspects of geology and geochemistry, solid earth geophysics, space physics, and oceanography. The latter two fields are also covered by other M.I.T. departments, and joint programs not only are possible but are encouraged.

Graduates in the earth sciences typically pursue careers in universities, government agencies, and industrial firms where they are concerned with teaching, research, or management.

Students who wish to transfer into Course XII will, in general, be able to get full credit for subjects they have taken. Hence it should not be difficult for science and engineering students to transfer into the Department.

THE UNDERGRADUATE CURRICULA

Geology and Geophysics (Course XII)

The undergraduate programs in Course XII provide students with an opportunity to acquire competence in some aspect of the earth and planetary sciences as described above. They are designed to prepare the student for work in the leading graduate departments in geology and geophysics in the country.

Two programs are offered. Program 1, for geologists and geochemists, is built around a core of prescribed professional subjects and basic subjects in physics and chemistry; electives allow for additional work in the basic and applied sciences and in the earth sciences. Program 2, which encompasses solid earth and planetary geophysics, emphasizes physics and mathematics in the required core; electives are used to meet the departmental requirement for the senior-year subjects in earth sciences and for further work in related fields. While both programs are normally begun in the sophomore year, in some cases students may enter at the beginning of the third year. Both programs lead to the degree of Bachelor of Science in Earth Sciences.

1. GEOLOGY, GEOCHEMISTRY AND GEOLOGICAL OCEANOGRAPHY PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 195*)					
	Specific science and humanities and social science subjects.				**128**
	The subjects 8.03T, 12.231, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
	Laboratory Requirement (see page 49).				**12**
DEPARTMENTAL PROGRAM					
	Required Subjects				
5.60	CHEMICAL THERMODYNAMICS	4	0	8	
8.03T	PHYSICS III	5	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
12.231	GEOLOGY I	3	4	5	
12.232T	GEOLOGY II	3	4	5	
					60
	Restricted Electives				
	An approved sequence of subjects concentrating in some field. Copies of recommended programs in the fields of geochemistry, hard-rock geology, soft-rock geology, and geological oceanography may be obtained from departmental headquarters. Students who wish to take some other program must submit it for approval to the departmental committee on undergraduates.				**112**
	Unrestricted Electives[1]				**48**
	Total units required for the S.B. degree				**360**

[1] Schedules of students in Course XII, Program 1, may always be arranged to leave available 12 units of unrestricted elective in the second year.

THE SOLID EARTH AND PLANETARY GEOPHYSICS PROGRAM

A physically oriented earth sciences student pursues a sequence of subjects similar to that of a student in Physics (Course VIII), making use of the astronomy and earth and planetary sciences electives at the sophomore, junior, and senior levels.

2. SOLID EARTH, PLANETARY GEOPHYSICS AND GEOPHYSICAL OCEANOGRAPHY PROGRAM CURRICULUM

					Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 195*)					
	Specific science and humanities and social science subjects.				128
	The Science Distribution Requirement will be satisfied by 8.03T and 18.034 which are required in the Departmental Program, plus appropriate subjects (see page 48) totaling				12
	Laboratory Requirement (see page 49)				12
DEPARTMENTAL PROGRAM					
	Required Subjects				
8.03T	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
8.05	PHYSICS OF ATOMS AND MOLECULES	4	0	8	
8.06	THEORETICAL PHYSICS I	4	0	8	
8.07T	THEORETICAL PHYSICS II	4	0	8	
8.08T	THEORETICAL PHYSICS III	4	0	8	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.05	ADVANCED CALCULUS FOR ENGINEERS	3	0	9	
					96
	Restricted Electives Electives are chosen by the student in consultation with his advisor. They must include continuum mechanics; electives in astronomy, astrophysics, and earth and planetary science, and laboratory and/or field work.[1]				100
	Unrestricted Electives				36
Total units required for the S.B. degree					384

[1] Laboratory and field experience should be obtained following the advisor's recommendations regarding field work, oceanographic studies and a thesis.

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 earth and planetary scientists; 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

The undergraduate curriculum requirements are the same as for Course XII.

The graduate requirement is 66 units of graduate study and an acceptable thesis.

Physical Sciences (Course XII-B)

The School of Science offers a program in the physical sciences leading to the degree of Bachelor of Science without designation of field, on the recommendation of the Department of Geology and Geophysics. The program is directed by the Department of Geology and Geophysics but this implies no commitment for the student to follow a program in the Earth Sciences. The program serves the following purposes.

1. To enable students to delve more deeply into a different range of subjects than would be possible under a standard physical science course.

2. To enable qualified science students who do not wish to follow a standard physical science degree program to develop a more comprehensive science orientation than would be possible in a social science curriculum but a less stringent approach than would be possible through concentration in one field.

3. To enable those science students who are initially less definite about their future careers but who want a strong physical science background to obtain a degree in the School of Science without specialization.

4. To provide non-scientists among the undergraduates with an opportunity to obtain a background in science more intensive than is

possible under a social science curriculum but less intensive than that given to students concentrating in a specific field.

Faculty members from the Department of Geology and Geophysics will serve as a team of advisors for the program. The curriculum will be individually arranged in consultations with an advisor to meet the specific needs of the student. In addition to the general Institute requirements, each curriculum will contain a coherent set of science and engineering subjects and will specifically not be restricted to a sampling of all introductory subjects. The program aims to provide a broad, interdisciplinary and coherent education in science. It is anticipated that students in this curriculum will be qualified for admission to graduate studies in one of the physical, environmental or applied sciences.

Admission to the program will be by the approval of the advisory team only, during an experimental period in which the program will be evaluated.

The curriculum requirements for this degree are given below.

GENERAL INSTITUTE REQUIREMENTS	*Total units*
Specific science and humanities and social science subjects (see page 195)	128
Science Distribution Requirement (see page 48)	36
Laboratory Requirement (see page 49)	12
Restricted Electives	
Science, and in special cases, engineering subjects chosen with advisor's approval	120
Unrestricted Electives	64
Total units required for the S.B. degree	360

GRADUATE STUDY

Geology and Geophysics

The Department of Geology and Geophysics offers a wide choice of graduate study and research for specialization in geology, geochemistry, and solid earth and planetary geophysics. In the borderland between geology, geophysics, geochemistry, and another science, the student may arrange a program of study and research under supervision 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 with a thesis in the field of specialization.

The Department offers graduate students an unusual opportunity to pursue study and research in both theoretical and experimental aspects of the subjects. Modern laboratory facilities, electronic computers, 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 on departmental projects and with industrial organizations and government agencies.

Oceanography

M.I.T. and the Woods Hole Oceanographic Institution have established a joint program in oceanography which leads to jointly awarded degrees of Doctor of Philosophy or Doctor of Science. For details of this program, see the description on page 229.

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 selected by the student after his preparation and proposed program of study have been considered by an advisory committee. The actual program of advanced subjects and research leading to a graduate degree is arranged by the student and his faculty advisors, 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 advisors. 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 specializa-

tion 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 an appropriate Departmental 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 satisfy the language requirements of the Institute (see Section 3). Ordinarily this requirement should be satisfied by the time the General Examination is taken and before undertaking thesis research.

In general, students are required to take at least 24 units of approved study in another department.

Teaching and Research Assistants

The Department regularly appoints 45 to 50 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

NORMAN LEVINSON, SC.D.
Professor of Mathematics; Head of the Department
HARVEY PHILIP GREENSPAN, PH.D.
Professor of Applied Mathematics; Chairman, Committee on Applied Mathematics
KENNETH MYRON HOFFMAN, PH.D.
Professor of Mathematics; Chairman, Committee on Pure Mathematics
DANIEL BURRILL RAY, PH.D.
Professor of Mathematics; Executive Officer
WARREN AMBROSE, PH.D.
Professor of Mathematics
NESMITH CORNETT ANKENY, PH.D.
Professor of Mathematics
MICHAEL ARTIN, PH.D.
Professor of Mathematics
DAVID JOHN BENNEY, PH.D.
Professor of Applied Mathematics
PRESCOTT DURAND CROUT, PH.D.
Professor of Mathematics
JAMES GILBERT GLIMM, PH.D. (*Absent*)
Professor of Mathematics
SIGURDUR HELGASON, PH.D.
Professor of Mathematics
FRANCIS BEGNAUD HILDEBRAND, PH.D.
Professor of Mathematics
LOUIS NORBERG HOWARD, PH.D. (*Absent*)
Professor of Mathematics
DANIEL MARINUS KAN, PH.D.
Professor of Mathematics
BERTRAM KOSTANT, PH.D.
Professor of Mathematics
ELLIOT HERSHEL LIEB, PH.D.
Professor of Applied Mathematics
CHIA-CHIAO LIN, PH.D.
Institute Professor; Professor of Applied Mathematics
WILLIAM TED MARTIN, PH.D. (*Absent*)
Professor of Mathematics
ARTHUR PAUL MATTUCK, PH.D.
Professor of Mathematics
JOHN WILLARD MILNOR, PH.D.
Alfred P. Sloan Professor of Mathematics
JAMES RAYMOND MUNKRES, PH.D.
Professor of Mathematics
SEYMOUR AUBREY PAPERT, PH.D.
Professor of Applied Mathematics (Visiting)
FRANKLIN PAUL PETERSON, PH.D.
Professor of Mathematics
LAJOS PUKANSZKY, PH.D.
Professor of Mathematics (Visiting)
ERIC REISSNER, DR. ING., PH.D. (*Absent*)
Professor of Applied Mathematics
HARTLEY ROGERS, JR., PH.D.
Professor of Mathematics
GIAN-CARLO ROTA, PH.D.
Professor of Mathematics
GERALD ENOCH SACKS, PH.D.
Professor of Mathematics
RICHARD DONALD SCHAFER, PH.D. (*Absent*)
Professor of Mathematics
IRVING EZRA SEGAL, PH.D.
Professor of Mathematics
CLAUDE ELWOOD SHANNON, PH.D.
Donner Professor of Science
ISADORE MANUAL SINGER, PH.D. (*Absent*)
Professor of Mathematics
ROBERT STEINBERG, PH.D.
Professor of Mathematics (Visiting)
GEORGE BRINTON THOMAS, JR., PH.D.
Professor of Mathematics
GEORGE PROCTOR WADSWORTH, PH.D.
Professor of Mathematics
GEORGE WILLIAM WHITEHEAD, PH.D.
Professor of Mathematics
DONALD WERNER ANDERSON, PH.D. (*Absent*)
Associate Professor of Mathematics
HUNG CHENG, PH.D.
Associate Professor of Applied Mathematics
EDWARD BALDWIN CURTIS, PH.D.
Associate Professor of Mathematics
RICHARD MANSFIELD DUDLEY, PH.D.
Associate Professor of Mathematics
VICTOR WILLIAM GUILLEMIN, PH.D.
Associate Professor of Mathematics
CHRISTOPHER HUNTER, PH.D.
Associate Professor of Applied Mathematics
DANIEL J. KLEITMAN, PH.D.
Associate Professor of Mathematics
TAKESHI KOTAKE, DR.SCI. (*Absent*)
Associate Professor of Mathematics
DANIEL GRAY QUILLEN, PH.D. (*Absent*)
Associate Professor of Mathematics
HAROLD MEAD STARK, PH.D.
Associate Professor of Mathematics
WILLIAM GILBERT STRANG, PH.D.
Associate Professor of Mathematics
ALAR TOOMRE, PH.D.
Associate Professor of Applied Mathematics
VICTOR BARCILON, PH.D.
Assistant Professor of Applied Mathematics
NORMAN BLEISTEIN, PH.D.
Assistant Professor of Applied Mathematics
MANUEL BLUM, PH.D. (*Absent*)
Assistant Professor of Applied Mathematics
ROE WILLIAM GOODMAN, PH.D. (*Absent*)
Assistant Professor of Mathematics
STEPHEN GROSSBERG, PH.D.
Assistant Professor of Applied Mathematics
VED PRAKASH MAINRA, PH.D.
Assistant Professor of Mathematics (Visiting)
BERNARD MASKIT, PH.D.
Assistant Professor of Mathematics

Science

DEPARTMENT OF MATHEMATICS

STEVEN ALAN ORSZAG, PH.D.
Assistant Professor of Applied Mathematics
COLIN JOHN THOMPSON, PH.D.
Assistant Professor of Applied Mathematics
FREDERIC YUI-MING WAN, PH.D.
Assistant Professor of Applied Mathematics

Lecturers

LUIS BAEZ-DUARTE, PH.D.
RODNEY JAMES BAXTER, PH.D.
WILLIAM LAWRENCE BLACK, SC.D.
ELIZABETH JEAN O'NEIL, PH.D.
STEPHEN SCHEINBERG, PH.D.

C. L. E. Moore Instructors

JOHN TUCKER CANNON, PH.D.
LAWRENCE JAY CORWIN, PH.D.
HELMUT PAVLOVICH EPP, PH.D.
DAVID LEWIS FRANK, PH.D.
JOHN MOORE FRANKS, PH.D.
STEPHEN HOWARD FRIEDBERG, PH.D.
KENNETH DAVID JOHNSON, PH.D.
NANCY JANE KOPELL, PH.D.
MALAYATTIL RABINDRANATHAN, PH.D.
BRUCE LEE ROTHSCHILD, PH.D.
SHANKAR SEN, PH.D.
BERNARD SHIFFMAN, PH.D.
ROBERT STEPHEN STRICHARTZ, PH.D.

Instructors

ROBERT FREDERICK VENNING ANDERSON, PH.D.
FRANK DAVID ANGER, PH.D.
ROBERT FRANCIS BERGERON, JR., PH.D.
HARRIET JANE FELL, S.B.
STEPHEN DAVID FISHER, PH.D.
SANDY GRABINER, PH.D.
STEPHEN JAMES GREENFIELD, PH.D.
JOHN ROBB HARPER, PH.D.
JULIEN OLIVER HENNEFELD, PH.D.
CHARLES HENRY JEPSEN, PH.D.
PHILIP OTTO KOCH, S.B.
MANUEL LERMAN, PH.D.
KENNETH CARY MILLETT, PH.D.
DAVID LAWRENCE RAGOZIN, PH.D.
DANIEL AARON SANKOWSKY, PH.D.
WILLIAM MERRILL SINGER, PH.D.
KAREN KESKULLA UHLENBECK, PH.D.
GAYN BURNS WINTERS, A.B.

Administrative Assistants

JAMES EDWARD DALTON,
JOHN ARTHUR MITCHELL, A.B.

Professors Emeriti

RAYMOND DONALD DOUGLASS, PH.D., SC.D.
Professor of Mathematics, Emeritus
HENRY BAYARD PHILLIPS, PH.D., LL.D.
Professor of Mathematics, Emeritus
DIRK JAN STRUIK, PH.D.
Professor of Mathematics, Emeritus

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.

CURRICULUM OF MATHEMATICS PROGRAM 1 — *Total units*

GENERAL INSTITUTE REQUIREMENTS (*see page 195*)

Specific science and humanities and social science subjects		128
The Science Distribution Requirement will be satisfied by 18.034, which is required in the Departmental Program, plus appropriate subjects (see page 48) totaling		24
Laboratory Requirement (see page 49)		12

DEPARTMENTAL PROGRAM

Required Subjects

18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.21	ANALYSIS	3	0	9	
	[1]LANGUAGE	4	0	8	
					36
	Restricted Electives	at least			96
	An integrated program of mathematics and advanced professional subjects in the Schools of Science and Engineering consisting of 96 units, of which at least 72 must be in the field of mathematics. In fulfilling this program, the following four requirements must be satisfied				
	1. *Either*				
18.20	LINEAR ALGEBRA	3	0	9	
	or the following combination:				
18.25	MODERN ALGEBRA *and*	3	0	9	
18.26	MODERN ALGEBRA	3	0	9	
	2. *Either*				
18.22	ANALYSIS	3	0	9	
	or				
18.31	THEORY OF FUNCTIONS	3	0	9	
	or				
18.49	HARMONIC ANALYSIS AND POTENTIAL THEORY	3	0	9	
	3. *Either*				
18.24	ELEMENTARY DIFFERENTIAL GEOMETRY	3	0	9	
	or the following combination:				
18.241	INTRODUCTION TO TOPOLOGY	3	0	9	
	and				
18.242	RIEMANNIAN GEOMETRY	3	0	9	
	4. *Either*				
18.23	SENIOR SEMINAR IN MATHEMATICS	3	0	9	
	or				
	THESIS		12		
	or				
	Advanced mathematics subject at the undergraduate or graduate level	3	0	9	
	Unrestricted Electives	up to			64
Total units required for the S.B. degree					360

CURRICULUM OF MATHEMATICS PROGRAM 2 — *Total units*

GENERAL INSTITUTE REQUIREMENTS (*see page 195*)

Specific science and humanities and social science subjects		128
The Science Distribution Requirement will be satisfied by 8.03T and 18.034, which are required in the Departmental Program, plus appropriate subjects (see page 48) totaling		12
Laboratory Requirement (see page 49)		12

DEPARTMENTAL PROGRAM

Required Subjects

8.03T	PHYSICS III	5	0	7	
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
18.21	ANALYSIS	3	0	9	
18.651	INTRODUCTION TO APPLIED MATHEMATICS	3	0	9	
	[1]LANGUAGE	4	0	8	
					60
	Restricted Electives	at least			84
	An integrated program of mathematics and advanced professional subjects in the Schools of Science and Engineering consisting of 84 units, of which at least 60 must be in the field of mathematics. In fulfilling this program, the following four requirements must be satisfied				
	1. *Either*				
18.20	LINEAR ALGEBRA	3	0	9	
	or the following combination:				
18.25	MODERN ALGEBRA *and*	3	0	9	
18.26	MODERN ALGEBRA	3	0	9	
	2. *Either*				
18.22	ANALYSIS *or*	3	0	9	
18.652	INTRODUCTION TO APPLIED MATHEMATICS	3	0	9	
	3. *Either*				
18.60	INTRODUCTION TO FLUID MECHANICS *or*	3	0	9	
18.66	INTRODUCTION TO ELASTICITY	3	0	9	
	4. *Either*				
18.23	SENIOR SEMINAR IN MATHEMATICS	3	0	9	
	or				
	THESIS		12		
	or				
	Advanced mathematics subject at the undergraduate or graduate level	3	0	9	
	Unrestricted Electives	up to			64
Total units required for the S.B. degree					360

[1] The language must be French, German, or Russian. Any student who has taken two 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 fluently mathematical literature in one of these languages may substitute 12 units of unspecified elective subjects for the language requirement.

Transfer from one program to the other may be made at any time. In either program the minimum algebra requirement is the one-term subject LINEAR ALGEBRA (18.20), but students wishing more work in algebra as undergraduates should take the two-term subject sequence in MODERN ALGEBRA (18.25, 18.26). For students following Program 1, the minimum requirement in geometry is the one-term subject ELEMENTARY DIFFERENTIAL GEOMETRY (18.24), but students wishing more work in geometry should take instead the two one-term subjects INTRODUCTION TO TOPOLOGY (18.241) and RIEMANNIAN GEOMETRY (18.242). Students interested in applied mathematics normally would follow Program 2, with INTRODUCTION TO APPLIED MATHEMATICS (18.652) recommended. It is strongly recommended that the requirements in algebra, analysis, and

introduction to applied mathematics be completed by the end of the third year, and that Physics 8.04 be included at an early stage in Program 2. The language requirement should be completed as early as possible.

It is also recommended that undergraduate students planning to pursue graduate work in elasticity, fluid mechanics, and related fields include the following elective subjects:

INTRODUCTION TO FUNCTIONS OF A COMPLEX VARIABLE (18.27, 18.28)
THEORETICAL PHYSICS I (8.06)

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.

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, each of which brings guest lecturers from other institutions.

Candidates whose primary interest is in the field of pure mathematics will ordinarily take most of their subjects in the Department of Mathematics. In addition to their advanced specialization, they will be encouraged to acquire breadth by taking basic subjects in analysis, algebra, geometry, and topology.

Candidates whose primary interest is 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.

Candidates primarily interested in pure mathematics which is basically motivated by applications and developments in theoretical physics or other disciplines will take special programs involving substantial breadth in both pure mathematics and the relevant cognate discipline.

Assistance or even collaboration in problems in pure or applied mathematics which are being investigated by members of the staff may constitute part of a graduate student's program.

Entrance Requirements for Graduate Study

The admission requirements are those set forth in Section 3 of this Catalogue, with the following additions and exceptions:

Science. Students are expected to have one year of college-level natural science.

Mathematics. Students will normally be expected to present an undergraduate mathematics program approximating that required of undergraduate mathematics majors at M.I.T. Students may enter the applied mathematics program from any undergraduate field of concentration and special consideration will be given to students with a strong scientific background.

The Graduate Degrees

MASTER OF SCIENCE IN MATHEMATICS

For the Master's degree, a student must take not less than 72 units including at least four 12-unit graduate ("A") subjects offered by the Department as well as submitting an acceptable thesis. With the approval of the registration officer two subjects may be taken from among the advanced undergraduate subjects offered by the Department. Where deemed appropriate, subjects from other Departments may be allowed.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE

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 should elect one of the following two plans of study:

Plan A, Qualifying Examination. A written qualifying examination on topics in algebra (primarily linear algebra), intermediate real analysis (based on a syllabus comparable to the current 18.21–18.22) and complex analysis (topics from 18.31). This examination will be given each year in November and in May. A graduate student is required to take the qualifying examination not later than the beginning of his second year (November). A student who has completed the necessary subjects before becoming a graduate student here should take this examination during his first year. The examination can be waived for students presenting to the Departmental Graduate Committee satisfactory evidence of having learned the material; for example, by having achieved sufficiently high standing in classes in these subjects at M.I.T. or elsewhere.

Plan B. All students electing Applied Mathematics as their field of study should normally follow this program. Its basic objective is a

proper balance of specialization and diversity. To secure maximum flexibility, each student's program is considered individually. The degree candidate, in consultation with a faculty advisor, submits a "Plan of Study" in his second term for approval by the Applied Mathematics Committee. In addition to a listing of subjects related to the major field, the plan must include a distinct minor, or its equivalent, to assure familiarity with the basic concepts of Applied Mathematics, i.e., propagation, equilibrium, stability, optimization, cybernetics and random processes. This plan forms the basis for the oral general examination which is arranged by the prospective thesis advisor and takes place in the second year of full-time graduate work. (The oral examination proposal is submitted to the Graduate Committee of the Department.) The student may officially begin his thesis research after passing this examination.

Students in both Plan A and Plan B will take additional subjects, chosen in consultation with an advisor. Unless otherwise specified by the advisor, 132 hours of graduate (A) credits with grade A or B are required. Where deemed advisable, subjects from other departments may be allowed.

A general oral examination is required of each candidate. The plan of this examination is made in consultation with three faculty members and is reviewed by the Graduate Committee.

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 oral examinations on their general mathematical progress.

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.

Thesis work is done under the supervision of an advisor. 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. The thesis examination committee consists of three members, including the advisor.

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
JULE GREGORY CHARNEY, PH.D.
Alfred P. Sloan Professor of Meteorology
EDWARD NORTON LORENZ, SC.D.
Professor of Meteorology
ERIK LEONARD MOLLÖ-CHRISTENSEN, SC.D.
Professor of Meteorology
NORMAN ALTON PHILLIPS, PH.D.
Professor of Meteorology
VICTOR PAUL STARR, PH.D.
Professor of Meteorology
HENRY MELSON STOMMEL, PH.D.
Professor of Oceanography
HURD CURTIS WILLETT, PH.D.
Professor of Meteorology, Emeritus; Senior Lecturer
JAMES MURDOCH AUSTIN, SC.D.
Associate Professor of Meteorology; Director of Summer Session
DELBAR POULEUR KEILY, S.B.
Associate Professor of Meteorology
REGINALD EDWARD NEWELL, SC.D.
Associate Professor of Meteorology
FREDERICK SANDERS, SC.D.
Associate Professor of Meteorology
ROBERT CRUCE BEARDSLEY, PH.D.
Assistant Professor of Oceanography
PETER BROOMELL RHINES, PH.D.
Assistant Professor of Oceanography

Senior Research Associates
PAULINE MORROW AUSTIN, PH.D., SC.D.
ALAN COGSWELL BEMIS, A.B., S.M.

Research Associate
SEELYE MARTIN, PH.D.

Professor Emeritus
HURD CURTIS WILLETT, PH.D.
Professor of Meteorology, Emeritus; Senior Lecturer

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 (COURSE XIX)

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.

METEOROLOGY

Formal subjects of instruction are offered in all of the principal areas of meteorology. Subjects commonly taken by graduate students include:

19.15	LONG-RANGE FORECASTING
19.22	AIR AND SEA INSTRUMENTS
19.24	FLUID DYNAMICS LABORATORY
19.34	STATISTICAL METHODS IN METEOROLOGY
19.45	SYNOPTIC METEOROLOGY II
19.46	NUMERICAL WEATHER PREDICTION
19.53	SYNOPTIC LABORATORY
19.64	DYNAMIC METEOROLOGY II
19.65	TURBULENCE AND RANDOM PHENOMENA IN FLUID MECHANICS
19.67	PLANETARY FLUID DYNAMICS
19.71	ATMOSPHERIC PRECIPITATION PROCESSES
19.72	PHYSICAL METEOROLOGY
19.74	PHYSICS OF THE UPPER ATMOSPHERE

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 and by facsimile. 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, IBM card equipment, and the high-speed computing facilities of the Information Processing Services 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 Fluid Dynamics Laboratory contains apparatus that models atmospheric and oceanic circulations.

The Department conducts an extensive program of sponsored research. Graduate students are often able to participate in this program as 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, 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.

OCEANOGRAPHY

The Department of Meteorology is an active participant in the joint M.I.T.-Woods Hole Oceanographic Institution graduate program in oceanography which is described in this section of the Catalogue on page 229. It is urged that candidates for the doctorate enter this joint program because of its many advantages. However, in special circumstances, a student may pursue a doctorate entirely under the auspices of the Department. The degree of Master of Science in Oceanography is offered by the Department but not in the joint program. The Master of Science degree is not a prerequisite to the doctorate but many students find it desirable to earn a Master of Science on the way to the doctorate. The Department is active in physical oceanography including theoretical studies of the oceanic circulation, observational studies at sea, laboratory models and field and laboratory investigations of the interactions between the atmosphere and the ocean. The programs of graduate students in oceanography also include subjects in oceanography and related areas offered by the Department of Geology and Geophysics, several other M.I.T. departments and the Woods Hole Oceanographic Institution.

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) and INTRODUCTION TO DYNAMICAL 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 Oceanog-

raphy, Doctor of Philosophy and Doctor of Science.

The Graduate Degrees

MASTER OF SCIENCE IN METEOROLOGY OR IN OCEANOGRAPHY

The 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 AND DOCTOR OF SCIENCE

The general requirements for the degrees of Doctor of Philosophy and Doctor of Science are given in Section 3. The language requirement as stated therein may be satisfied by almost any modern language or languages other than English because of the international nature of the fields of meteorology and oceanography. If there are no other important considerations it is suggested that the language or languages be chosen from Russian, German, French and Spanish. It is suggested that students take two years of a suitable foreign language as a part of their undergraduate preparation which will satisfy the language requirement. Students are strongly urged to satisfy the language requirement at the earliest possible time and in no event later than the end of their second graduate year.

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 and Food Science

NEVIN STEWART SCRIMSHAW, PH.D., M.D., D.P.S.
Professor of Nutrition; Head of the Department

SAMUEL ABRAHAM GOLDBLITH, PH.D.
Professor of Food Science; Deputy Head of the Department

JOSEPH CHIKE EDOZIEN, M.D.
Professor of Clinical Nutrition (Visiting)

LEO FRIEDMAN, PH.D.
Professor of Nutrition and Food Safety

ROBERT SAMUEL HARRIS, PH.D.
Professor of Nutritional Biochemistry

HAMISH NISBET MUNRO, M.D., D.SC.
General Foods Professor of Physiological Chemistry

PAUL MEDFORD NEWBERNE, D.V.M., PH.D.
Professor of Nutritional Pathology

JOHN THEODORE ROOSEVELT NICKERSON, PH.D.
Professor of Food Technology

ABRAHAM DANIEL RUBENSTEIN, M.D.
Professor of Epidemiology (Visiting)

JOHN BRUTON STANBURY, M.D.
Professor of Experimental Medicine

EMILY LIPPINCOTT WICK, PH.D.
Professor of Food Chemistry; Associate Dean of Student Affairs

LESLIE J. DEGROOT, M.D.
Associate Professor of Experimental Medicine

CECIL GORDON DUNN, PH.D.
Associate Professor of Industrial Microbiology

PHILLIP ISSENBERG, PH.D.
Associate Professor of Food Science

MARCUS KAREL, PH.D.
Associate Professor of Food Engineering

RICHARD ISAAC MATELES, SC.D. *(Absent)*
Associate Professor of Biochemical Engineering

SANFORD ARTHUR MILLER, PH.D.
Associate Professor of Nutritional Biochemistry

JUAN MARCELO NAVIA, PH.D.
Associate Professor of Nutritional Biochemistry

GERALD SILVERMAN, PH.D.
Associate Professor of Food Microbiology

GERALD NORMAN WOGAN, PH.D.
Associate Professor of Food Toxicology

GEORGE WOLF, D.PHIL.
Associate Professor of Physiological Chemistry

RICHARD J. WURTMAN, M.D.
Associate Professor of Endocrinology and Metabolism

EDWIN DAGOBERT BRANSOME, JR., M.D.
Assistant Professor of Endocrinology and Metabolism

JAMES WALLACE DRYSDALE, PH.D.
Assistant Professor of Physiological Chemistry

CHARLES EBENEZER HUNT, D.V.M.
Assistant Professor of Pathology

THEODORE PETER LABUZA, PH.D.
Assistant Professor of Food Engineering

RONALD CARLYLE SHANK, PH.D.
Assistant Professor of Food Toxicology

ANTHONY JOHN SINSKEY, SC.D.
Assistant Professor of Food Microbiology

STEVEN ROBERT TANNENBAUM, PH.D.
Assistant Professor of Food Science

DANIEL I. C. WANG, PH.D.
Assistant Professor of Biochemical Engineering

VERNON ROBERT YOUNG, PH.D.
Assistant Professor of Physiological Chemistry

Administrative Officer

PAUL HENRY QUINN

Senior Lecturers

JOHN EVERETT GORDON, PH.D., M.D.
HUGO MUENCH, JR., D.P.H., M.D.

Lecturers

AARON M. ALTSCHUL, PH.D. *(Visiting)*
GUILLERMO ARROYAVE, PH.D. *(Visiting)*
RICARDO BRESSANI, PH.D. *(Visiting)*
CHARLEY ELMER GILMORE, D.V.M.
MIGUEL A. GUZMAN, PH.D. *(Visiting)*
EMANUEL S. HELLMAN, M.D.
RONALD DUNCAN HUNT, D.V.M.
ARNOLD JOHN LEHMAN, PH.D., M.D. *(Visiting)*
CHARLES MERRITT, JR., PH.D.
GEORGE NICHOLS, JR., M.D.
H. A. B. PARPIA, PH.D. *(Visiting)*
JOHN T. POTTS, JR., M.D.

Instructor

JEAN PIERRE FLATT, PH.D.

Administrative Assistant

CHARLES FREDERICK BENTLEY, II

Research Associates

SYED QAMAR ALAM, PH.D.
BANTVAL SURENDRA BALIGA, PH.D.
ULRICH KASPAR BUHLER, M.D.
LEROY DONALD CAGNONE, D.D.S.
LUIGI DE LUCA, PH.D.
JANIS Z. GABLIKS, PH.D.
OTTO GEORGE GLASER, M.D.
GERALD NATHAN GOLD, M.D.
JOHN EVERETT HARRIS, PH.D.
SONJA ELAINE HICKS, PH.D.
DONALD LEE HOLMQUEST, M.D., PH.D.
EVA HONOVA, R.N.DR.
MOHAMMED AMR HUSSEIN, M.P.H.
SAMSON THEKKEKARA JACOB, PH.D.
ZVI MARKUS, PH.D.
ABRAHAM EDWARD NIZEL, D.M.D., M.S.D.
YUCHIO OCHI, M.D.
LARISSA ALEXANDRA POHORECKY, PH.D.
PIERGIORGIO RIGHETTI, PH.D.
ADRIANNE ELLEFSON ROGERS, M.D.
UDO UKWENI UDO, M.B.CH.B.
SHMUEL YANNAI, D.SC.
MICHAEL JONATHAN ZIGMOND, PH.D.

Science

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

NUTRITION AND FOOD SCIENCE

The biological sciences have in recent years undergone a dramatic expansion and development. Nutrition and food science have also fallen under the influence of this change. In the past, nutrition was traditionally concerned with requirements for specific nutrients, and food science with practical means for food preservation. Concomitant with the recent dramatic developments in life sciences, physical sciences and engineering, these disciplines have acquired a broader context, requiring the application of modern, quantitative principles and techniques to many aspects of the relationship of man to his environment. The Department of Nutrition and Food Science, by virtue of the diverse interests and backgrounds of its faculty, integrates knowledge from chemistry, physics, microbiology, medicine and engineering in research and teaching programs dealing with fundamental problems in nutritional biochemistry and metabolism, food science and technology, and biochemical engineering.

Problems associated with the increasing world population and with the rapid application of scientific and technological discoveries by both medicine and the food industry present an unprecedented challenge for nutrition and food scientists. The prevalence of malnutrition in technically underdeveloped countries and of degenerative diseases in the technically advanced countries; the need for improved understanding of the origin and nature of human disease and disability; the variety of new compounds being added intentionally or finding their way unintentionally into man's food; the need for new and improved methods of food processing and for prolonged storage and widespread distribution of foodstuffs — these are among the problems that have increased the need for fundamental scientific information about human nutrition and metabolism and human food supply and for ways of applying such information for the welfare of mankind. In response to the challenge of these problems, a broad and integrated Department of Nutrition and Food Science has been developed at M.I.T. The staff of the Department includes scientists trained in medicine and public health, animal nutrition and pathology, physiology and physiological chemistry, food toxicology and microbiology, food and flavor chemistry, and food processing and engineering. The Department thus offers interdisciplinary training to students planning careers in these fields.

The Department is cooperating with the Pan American Health Organization 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 provide a better opportunity for the training of students who plan to participate in this work.

Among the variety of careers open to students with training in nutrition, food science and technology are: university teaching and research, research in government, private and industrial laboratories; product and process development in the food and related industries; work with international agencies.

UNDERGRADUATE SPECIALIZATION IN NUTRITION AND FOOD SCIENCE

This Department offers an undergraduate curriculum as part of the Life Sciences Curriculum Program 3. This curriculum (described below) emphasizes fundamental subjects in the physical and biological sciences. These, together with the subjects prescribed under the General Institute Requirements (page 195), provide the undergraduate student with the broad background in basic sciences which is necessary either for an understanding of food science or of the adaptive responses of mammals to nutritional and other environmental factors. Either of two fields of specialization may be elected. For those interested in nutrition, introductory subjects are taken in nutrition, biochemistry, mammalian physiology; and a series of planned electives may be chosen from areas which include physiological chemistry, human nutrition, endocrinology, neuroendocrinology, and psychology. For those interested in specializing in food science and technology, a series of planned electives may be selected from subjects such as food engineering, analytical chemistry, physiology, microbiology, and food toxicology. Although most of the specialized training in food science and technology and nutritional biochemistry and metabolism must be obtained at the graduate level, the undergraduate student may sample these fields while acquiring knowledge which will serve him well in a broad range of careers in the life sciences.

Life Sciences (Course VII)

PROGRAM 3. NUTRITION AND FOOD SCIENCE CURRICULUM

				Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 195*)				
Specific science and humanities and social science subjects				**128**
The subjects 5.41, 7.01, and 18.034, which are required in the Departmental Program, appear on the list of Science Distribution Subjects (see page 48) and can be used to satisfy the Science Distribution Requirement.				
The laboratory subjects 7.02 or 20.02 may be used to satisfy the Institute Laboratory Requirement of 12 units (see page 49).				
DEPARTMENTAL PROGRAM				
Required Subjects				
5.41 ORGANIC CHEMISTRY I	4	0	8	
5.31 INTRODUCTION TO CHEMICAL EXPERIMENTATION	2	8	2	
5.60 CHEMICAL THERMODYNAMICS	4	0	8	
7.01 GENERAL BIOLOGY	4	0	8	
7.05 GENERAL BIOCHEMISTRY	4	0	6	
7.051 GENERAL BIOCHEMISTRY LABORATORY	0	8	0	
7.21 GENERAL MICROBIOLOGY	3	0	6	
18.034 DIFFERENTIAL EQUATIONS	3	0	9	
20.30T NUTRITIONAL BIOCHEMISTRY AND METABOLISM	4	0	8	
				99
Restricted Electives				
One of the following subjects:				
8.03T PHYSICS III	5	0	7	
1.00 INFORMATION SYSTEMS	3	3	6	
6.01 INTRODUCTORY NETWORK THEORY	4	0	8	
One of the following subjects:				
7.02 GENERAL BIOLOGY LABORATORY	1	8	3	
20.02 NUTRITION AND FOOD SCIENCE PROJECTS LABORATORY	1	8	3	
One of the following subjects:				
5.62 PHYSICAL CHEMISTRY	4	0	8	
5.63 PHYSICAL CHEMISTRY	4	0	8	
One of the following:				
(a) *Food Science*				
20.11 FOOD SCIENCE AND TECHNOLOGY	3	0	5	
and				
20.41 MICROBIOLOGY LABORATORY	2	4	3	
or				
(b) *Nutrition*				
20.38 FACTORS DETERMINING FOOD VALUE	3	0	6	
and				
20.63 SYSTEMIC PHYSIOLOGY	3	0	6	
				53 or **54**
Unrestricted Electives[1]				**80** or **79**
Total units required for S.B. degree				**360**

[1] Schedules of students in Course VII, Program 3, may always be arranged to leave available 24 units of unrestricted elective in the second year. A thesis is recommended but not required.

GRADUATE STUDY (COURSE XX)

The Department of Nutrition and Food Science offers advanced programs in Nutritional Biochemistry and Metabolism, in Food Science and Technology, and in Biochemical Engineering leading to the degrees of Master of Science, Doctor of Philosophy, and Doctor of Science.

The Department offers a wide choice of graduate study and research with opportunities for specialization in clinical and public health nutrition, animal nutrition, physiological chemistry, food toxicology, food chemistry, flavor chemistry, food microbiology, food processing, food engineering, and biochemical engineering. It also offers special programs for veterinarians wishing to undertake advanced training in animal pathology and physiological chemistry or in food science. Physicians and dentists wishing to undertake advanced training in nutrition and related sciences may also become degree candidates.

The Department has excellent facilities for research which include a clinical research center for metabolic studies on human subjects; well-equipped laboratories for physical, chemical, biochemical and microbiological research; modern animal laboratories; and processing laboratories for research on the effects on foods of heat, refrigeration, freezing, dehydration, radiation, and fermentation.

NUTRITIONAL BIOCHEMISTRY AND METABOLISM

Research in nutritional biochemistry and metabolism is concerned with nutritional, genetic, environmental and endocrine variations in the metabolic processes of man and various laboratory animals and their alterations in disease states. Current research projects include: biochemical, morphological and physiological effects of malnutrition; the biochemical defects underlying inherited disorders of the endocrine system; endocrine control mechanisms; effects of infection and physical and mental stress on nutrient requirements and nutritional status; dietary and hormonal factors influencing protein synthesis; effects of amino acid imbalances; environmental factors influencing endocrine rhythms; protein digestion and biological availability of amino acids in foods; enzyme synthesis and turnover in tissues; utilization in metabolism of synthetic compounds as energy sources; functions of vitamin A in the metabolism of amino acids and related compounds; electron transport and energy availability in endocrine organs; protein and nucleic acid synthesis and turnover in endocrine tissues and their control; the role of diet in the development of dental caries; biological activities of fatty acids; effects of nutritional and endocrine variations on the activities

of tissue enzymes; congenital defects due to vitamin deficiencies; and nutrient requirements and food for space exploration.

A program of training in nutritional biochemistry is offered to those graduate students who want to acquire knowledge and research experience in physiological chemistry and biochemistry as it applies to nutritional problems. To this end, several advanced subjects in nutritional biochemistry have been instituted. The staff of the Department also carry out research into the regulation of protein synthesis in mammals by nutritional and hormonal factors, into vitamin and amino acid metabolism and function, into the metabolism of sulfur amino acids and into the nutrition of newborn mammals. There is a close relationship to modern biological studies, the knowledge gained being in the area of the effect of the environment, and especially the nutritional environment, on the functioning of the whole organism.

FOOD SCIENCE

Research in food toxicology, food chemistry, and flavor chemistry is concerned with the occurrence of toxic substances in foods, composition of foods, changes in food composition due to chemical reactions, and with components contributing to the organoleptic properties (flavor) of foods. Current research projects include isolation, identification, and biosynthesis of fat soluble toxic compounds, and toxic compounds produced by molds; biochemical and physiological effects of other potential toxic substances found in foods; isolation and identification of the components contributing to food flavor; mechanism and kinetics of chemical reactions occurring in foods, and factors affecting food acceptability.

Food microbiology, food processing and food engineering deal with the establishment of scientific principles and engineering practices for the processing, storage, distribution and use of foods and with procedures for maintaining or improving their acceptability and nutritive value. Current research projects include effects of ionizing radiation on foods and micro-organisms; engineering properties of food materials and their effect on process design; heat and mass transfer factors in food processing and storage; colloidal and surface phenomena in food processing; ecological factors in the growth of pathogenic micro-organisms; factors causing deterioration of processed foods; and viability and mutation of micro-organisms under various environmental conditions, including those of outer space.

In biochemical engineering and industrial microbiology, current research projects include continuous culture of micro-organisms; microbial synthesis of amino acids; anaerobic growth of micro-organisms; dynamics of microbial growth, computer simulation of microbial systems; continuous centrifugation; and automatic control of nutrient concentration.

SPECIAL PROGRAMS

Food Toxicology

A program of training in food toxicology is offered for degree candidates in either nutritional biochemistry and metabolism or in food science and technology. This research area is concerned with the origin, occurrence and potential health hazards of toxic substances in foods. Of major interest are contaminants entering the food chain accidentally, such as microbial toxins, residues of materials (pesticides, preservatives, etc.) used in food production or toxic components of foodstuffs not previously used for human consumption. Research areas include isolation and chemical characterization of toxic compounds; biochemical effects of toxic substances in animal tissues; effects of chemical carcinogens on nucleic acid metabolism; chemical carcinogenesis; and development of new methods for toxicologic investigations.

Clinical Nutrition and Metabolism

Persons who hold the M.D. or equivalent degree from an acceptable medical school and who have completed at least one year of internship or equivalent postdoctoral training may apply for admission to the Graduate School as candidates for the degree of Master of Science in Nutritional Biochemistry and Metabolism or Doctor of Philosophy. Such individuals will be required to present credentials indicating a basic science background equivalent to those described for holders of baccalaureate degrees. Provision may be made for making up minor academic deficiencies after admittance.

The Department administers a clinical research center for metabolic studies on both hospitalized patients and ambulatory subjects.

Oral Science

Research in disorders of the teeth and soft tissues of the mouth requires a thorough knowledge of the basic sciences, including the use of special techniques and instruments. The program in oral science in the Department, supported by a grant from the National Institute of

Dental Research, is designed to prepare graduate students, postdoctoral dental investigators, and others for research careers in oral science. It is expected that at the end of the training program such students will have completed requirements for the Ph.D. or Sc.D.

Veterinary Pathology and Nutritional Biochemistry and Metabolism

A program is offered for veterinary graduates wishing to obtain a doctorate based on the study of animal pathology and nutritional biochemistry and metabolism. This program satisfies a part of the requirements for the Board examinations of the American College of Veterinary Pathology. Special fellowships are available.

Experimental Medicine

The Unit of Experimental Medicine is concerned in teaching and research related to human disease, especially endocrinology and metabolism. Investigations in progress involve studies in hormone action at the cellular level and the nature of metabolic disturbances which are found in, or result in human disease. The members of the Unit participate in the activities of the Clinical Research Center where patients with endocrine and metabolic disease are received for intensive investigation. Postdoctoral Fellows are received for intensive training in the application of scientific disciplines to disease problems. Members of the Unit also receive graduate students for training in scientific disciplines related to medical science and for disease oriented research.

Food Science for Veterinarians

Veterinarians have long been concerned with maintenance of food safety for both civilian and military purposes. Recognizing the need for training veterinarians in food science and technology for the armed forces and for civilian work throughout the world, the Department has established a program of study leading to the degree of Master of Science in Food Science and Technology.

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, provision is made for a limited number of qualified students to do their thesis research while in residence in Guatemala. This program offers students a unique opportunity to study the serious nutritional and food problems characteristic of many technically underdeveloped areas of the world.

Physicians and dentists who are candidates for a degree ordinarily will be required to take the subjects PUBLIC HEALTH NUTRITION, CLINICAL NUTRITION, and EVALUATION OF NUTRITIONAL STATUS which are given in Guatemala during the summer term.

Entrance Requirements for Graduate Study

The general requirements for admission to the Graduate School are given in Section 3 of this Catalogue. The Department modifies the Institute requirements for graduate study to one year each of calculus and physics.

To qualify for graduate study in the Department of Nutrition and Food Science, a student should have a Bachelor's degree with a major in nutrition, food science, food technology, chemistry, biology, or chemical engineering or in one of the medical, agricultural or other physical sciences with a strong background in chemistry; or an M.D., D.D.S., D.M.D., or D.V.M. degree. He should have a superior record in his undergraduate work. Basic subjects in calculus and physics and in analytical, organic, and physical chemistry are required for qualification. Students with minor deficiencies may be admitted with the understanding that such deficiencies will be made up during the first year of graduate study.

The Graduate Degrees

MASTER OF SCIENCE IN NUTRITIONAL BIOCHEMISTRY AND METABOLISM; MASTER OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY

Students who have a Bachelor of Science degree in Life Sciences at M.I.T. or equivalent training may attain a Master of Science degree in Nutritional Biochemistry and Metabolism or in Food Science and Technology in one year. The general requirements for the Master of Science degree are set forth in Section 3. A thesis based on original research directed by a faculty member is required of all candidates for this degree.

For the degree of Master of Science in Nutritional Biochemistry and Metabolism, the following graduate subjects are strongly recommended:

TECHNIQUES IN FOOD AND NUTRITION RESEARCH (20.32)
HUMAN NUTRITION (20.36)
SEMINAR IN NUTRITION AND FOOD SCIENCE (20.61, 20.62).

For the degree of Master of Science in Food Science and Technology, the following graduate subjects are strongly recommended:

TECHNIQUES IN FOOD AND NUTRITION RESEARCH (20.32)
FOOD MICROBIOLOGY (20.46)
or
ADVANCED FOOD SCIENCE (20.51)
SEMINAR IN NUTRITION AND FOOD SCIENCE (20.61, 20.62)

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 micro-organisms, chemical engineering, or industrial management, again depending on the individual student's interests.

DOCTOR OF PHILOSOPHY OR DOCTOR OF SCIENCE

DOCTORAL PROGRAMS IN NUTRITIONAL BIOCHEMISTRY AND METABOLISM OR FOOD SCIENCE AND TECHNOLOGY

The choice of subjects in these programs depends on each student's background, his aptitudes, and his future plans. Opportunities are provided for advanced study and research in the various fields of specialization described above. The Department Committee on Graduate Students assists with the planning of programs.

Candidates for the doctorates must demonstrate *either* substantial competence in speaking and reading one modern language in addition to English *or* ability to read and translate the scientific literature of their field of specialization from two modern foreign languages into English.

Students are expected to prepare themselves for comprehensive written and oral examinations within three years. The examination is designed to test the student's knowledge of the fundamentals of his field of specialization and his ability to utilize his knowledge of the basic sciences in solving modern problems in nutrition, food science, and food technology.

A thesis based on original research is required of all candidates for the Doctor of Philosophy and Doctor of Science degrees.

The time required for the Doctor of Philosophy or Doctor of Science degree will vary with the individual. A superior candidate with undergraduate training equivalent to that given at M.I.T. can complete the Doctor of Philosophy or Doctor of Science degree in three and one-half years of full-time work.

DOCTORAL PROGRAMS IN BIOCHEMICAL ENGINEERING

No rigid sequence of graduate subjects is specified in this program. 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 and Food Science; Biology; and Chemical Engineering. Doctoral examinations, which are prepared and conducted by this committee, follow the pattern described above for nutrition, food science and technology and include a general written and an oral examination.

Fellowships and Assistantships

Students who are considering graduate study in the Department of Nutrition and Food Science are encouraged to apply for assistantships. Funds are available to support qualified graduate students as research assistants throughout their graduate careers. Many of the available research assistantships are supported by research grants obtained by members of the faculty for work on specific projects of interest to them.

A number of fellowships are available for postdoctoral study in either nutrition or food science. Fellowships are also available for American citizens through the Public Health Service Training Grants Program in the fields of nutrition, nutritional pathology, food toxicology, food science and technology, and biochemical engineering.

Applicants wishing to be considered for assistantships or fellowships should so indicate in a letter to the Head of the Department which may be included with the completed application. The letter should indicate clearly the applicant's objectives in undertaking graduate study.

Department of Physics

VICTOR FREDERICK WEISSKOPF, PH.D. SC.D.
Institute Professor; Professor of Physics; Head of the Department

ALBERT GORDON HILL, PH.D.
Professor of Physics; Chairman, Physics Council

GEORGE GRAHAM HARVEY, PH.D.
Professor of Physics; Executive Officer; Associate Director of the Research Laboratory of Electronics

WILLIAM PHELPS ALLIS, SC.D.
Professor of Physics, Emeritus; Senior Lecturer

WALTER CARLISLE BARBER, PH.D.
Professor of Physics

ALAN HILDRETH BARRETT, PH.D.
Professor of Physics

GEORGE BEKEFI, PH.D.
Professor of Physics

GEORGE BERNARD BENEDEK, PH.D.
Professor of Physics

WILLIAM BERTOZZI, PH.D.
Professor of Physics

WAYNE ALEXANDER BOWERS, PH.D.
Professor of Physics (Visiting)

HERBERT SAGE BRIDGE, PH.D.
Professor of Physics; Associate Director of the Center for Space Research

SANBORN CONNER BROWN, PH.D. (*Absent*)
Professor of Physics; Associate Dean of the Graduate School

WILLIAM WEBER BUECHNER, PH.D.
Professor of Physics

BERNARD FLOOD BURKE, PH.D.
Professor of Physics

GEORGE WHIPPLE CLARK, PH.D.
Professor of Physics

BRUNO COPPI, PH.D.
Professor of Physics

PETER THEODORE DEMOS, PH.D.
Professor of Physics; Director of the Laboratory for Nuclear Science

MARTIN DEUTSCH, PH.D., SC.D.
Professor of Physics

HARALD ANTON ENGE, DR.PHIL.
Professor of Physics

ROBLEY DUNGLISON EVANS, PH.D.
Professor of Physics

BERNARD TAUB FELD, PH.D.
Professor of Physics

HERMAN FESHBACH, PH.D.
Professor of Physics

NATHANIEL HERMAN FRANK, SC.D.
Professor of Physics, Emeritus; Senior Lecturer

ANTHONY PHILIP FRENCH, PH.D.
Professor of Physics

JEROME ISAAC FRIEDMAN, PH.D.
Professor of Physics

DAVID HENRY FRISCH, PH.D.
Professor of Physics

SERGIO PIERO FUBINI, DR.
Professor of Physics

KURT GOTTFRIED, PH.D.
Professor of Physics (Visiting)

LEE GRODZINS, PH.D.
Professor of Physics

GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D., D.ENG.
Professor of Physics, Emeritus

KERSON HUANG, PH.D.
Professor of Physics

ROBERT INSLEE HULSIZER, JR., PH.D.
Professor of Physicss

ICKO IBEN, JR., PH.D.
Professor of Physics

KARL UNO INGARD, PH.D.
Professor of Physics

ALI JAVAN, PH.D.
Professor of Physics

KENNETH ALAN JOHNSON, PH.D.
Professor of Physics

HENRY WAY KENDALL, PH.D.
Professor of Physics

ARTHUR KENT KERMAN, PH.D.
Professor of Physics

JOHN GORDON KING, PH.D.
Professor of Physics

GEORGE FRED KOSTER, PH.D.
Professor of Physics

BENJAMIN LAX, PH.D.
Professor of Physics; Director of the National Magnet Laboratory

MILTON STANLEY LIVINGSTON, PH.D., SC.D. (*Absent*)
Professor of Physics

FRANCIS EUGENE LOW, PH.D.
Professor of Physics

PHILIP MORRISON, PH.D.
Professor of Physics

PHILIP McCORD MORSE, PH.D., SC.D.
Professor of Physics; Director of the Operations Research Center

STANISLAW OLBERT, PH.D.
Professor of Physics

LOUIS SHREVE OSBORNE, PH.D.
Professor of Physics

IRWIN ABRAHAM PLESS, PH.D.
Professor of Physics

ISADOR ISSAC RABI, PH.D.
Karl Taylor Compton Professor of Physics (Visiting)

LAWRENCE ROSENSON, PH.D.
Professor of Physics

BRUNO BENEDETTO ROSSI, PH.D.
Institute Professor; Professor of Physics

PETER SCHOFIELD
Professor of Physics (Visiting)

Science

DEPARTMENT OF PHYSICS

IRWIN IRA SHAPIRO, PH.D.
Professor of Geophysics and Physics

CLIFFORD GLENWOOD SHULL, PH.D.
Professor of Physics

JOHN CLARKE SLATER, PH.D., SC.D.
Institute Professor, Emeritus; Harry B. Higgins Professor of the Solid State, Emeritus

MALCOM WOODROW PERSHING STRANDBERG, PH.D.
Professor of Physics

LASZLO TISZA, PH.D.
Professor of Physics

GEORGE EDWARD VALLEY, JR., PH.D.
Professor of Physics

FELIX MARC HERMANN VILLARS, D.SC.
Professor of Physics

BERTRAM EUGENE WARREN, SC.D.
Professor of Physics, Emeritus; Senior Lecturer

STEVEN WEINBERG, PH.D.
Professor of Physics (Visiting)

JERROLD REINACH ZACHARIAS, PH.D., L.H.D., SC.D.
Institute Professor; Professor of Physics; Director of the Education Research Center

GENE ALLEN BARAFF, PH.D.
Associate Professor of Physics (Visiting)

ARON MYRON BERNSTEIN, PH.D.
Associate Professor of Physics

HALE VAN DORN BRADT, PH.D.
Associate Professor of Physics

JOHN BRAYTON BRONZAN, PH.D.
Associate Professor of Physics

THOMAS HENDERSON DUPREE, PH.D.
Associate Professor of Physics

DANIEL KLEPPNER, PH.D.
Associate Professor of Physics

GERD KOPPELMANN, DR.ING.
Associate Professor of Physics (Visiting)

WALTER H. G. LEWIN
Associate Professor of Physics

EARLE LEONARD LOMON, PH.D.
Associate Professor of Physics

LEO SARTORI, PH.D.
Associate Professor of Physics

CARL MARX SHAKIN, PH.D.
Associate Professor of Physics

ABRAHAM SZÖKE, PH.D.
Associate Professor of Physics

SAMUEL TING, PH.D.
Associate Professor of Physics

RAINER WEISS, PH.D.
Associate Professor of Physics

RICHARD KUMEO YAMAMOTO, PH.D.
Associate Professor of Physics

WILLIAM H. BASSICHIS, PH.D.
Assistant Professor of Physics

THOMAS ALEXANDER BELOTE, PH.D.
Assistant Professor of Physics

WILLIAM KEITH BERTRAM, PH.D.
Assistant Professor of Physics

JAMES RODGERS CLOW, PH.D.
Assistant Professor of Physics

ERIC RICHARD COSMAN, PH.D.
Assistant Professor of Physics

PETER DONALD DE CICCO, PH.D.
Assistant Professor of Physics

WILLIAM EDWIN DORENBUSCH, PH.D.
Assistant Professor of Physics

MICHAEL STEPHEN FELD, PH.D.
Assistant Professor of Physics

IRA STEPHEN GERSTEIN, PH.D.
Assistant Professor of Physics

THOMAS JOHN GREYTAK, PH.D.
Assistant Professor of Physics

CECIL EDWARD JONES, PH.D.
Assistant Professor of Physics

RAFAEL KALISH, PH.D.
Assistant Professor of Physics (Visiting)

ROBERT JOHN KOLENKOW, PH.D.
Assistant Professor of Physics

WILLIAM JOHN KOSSLER, PH.D.
Assistant Professor of Physics

STANLEY BENEDICT KOWALSKI, PH.D.
Assistant Professor of Physics

RICHARD CHARLES LANZA, PH.D.
Assistant Professor of Physics

ALAN JAY LAZARUS, PH.D.
Assistant Professor of Physics

JAMES DAVID LITSTER, PH.D.
Assistant Professor of Physics

HENRY J. LUBATTI, PH.D.
Assistant Professor of Physics

WALLACE MILTON MANHEIMER, PH.D.
Assistant Professor of Physics

DAVID CECIL MILLER, PH.D.
Assistant Professor of Physics

WILLIAM HENRY MOORE, PH.D.
Assistant Professor of Physics

JAMES WILCOX OVERBECK, PH.D.
Assistant Professor of Physics

RICHARD MARCUS PRICE, PH.D.
Assistant Professor of Physics

WILLIAM KENNETH ROSE, PH.D.
Assistant Professor of Physics

HERBERT WILLIAM SCHNOPPER, PH.D.
Assistant Professor of Physics

MARLAN ORVIL SCULLY, PH.D.
Assistant Professor of Physics

GEORGE LEONARD SISCOE, PH.D.
Assistant Professor of Physics

VIGDOR LOUIS TEPLITZ, PH.D.
Assistant Professor of Physics
KOSTA MICHAEL TSIPIS, PH.D.
Assistant Professor of Physics
VYTENIS MARIJA VASYLIUNAS, PH.D.
Assistant Professor of Physics
TERENCE LESLIE WATTS, PH.D.
Assistant Professor of Physics
BRADFORD LAWRENCE WRIGHT, PH.D.
Assistant Professor of Physics

Administrative Officer
DANIEL HENRY GOULD

Lecturers
FREDERIC JOHN EPPLING, PH.D.
Associate Director of the Laboratory for Nuclear Science
PAUL DAVID LUCKEY, JR., PH.D.
CHARLES PHILIP SARGENT, PH.D.
EDWIN FLORIMAN TAYLOR, PH.D.
WILLIAM ERNEST TURCHINETZ, PH.D.

Instructors
THOMAS KORFF GAISSER, PH.D.
ROBERT GILMORE, PH.D.
STEPHEN GEORGE KUKOLICH, SC.D.
DAVID EDWARD PRITCHARD, PH.D.
SAUL ALAN RAPPAPORT, PH.D.
KEITH FREDERICK RATCLIFF, PH.D.
CHIA-GEE WANG, PH.D.

Technical Instructor
HAROLD ADOLPH LUNDQUIST

Professors Emeriti
WILLIAM PHELPS ALLIS, SC.D.
Professor of Physics, Emeritus; Senior Lecturer
NATHANIEL HERMAN FRANK, SC.D.
Professor of Physics, Emeritus; Senior Lecturer
ARTHUR COBB HARDY, SC.D.
Professor of Optics and Photography, Emeritus
GEORGE RUSSELL HARRISON, PH.D., D.SC., LL.D., D.ENG.
Professor of Physics, Emeritus; Dean of the School of Science, Emeritus
JOHN CLARKE SLATER, PH.D., SC.D.
Institute Professor, Emeritus; Harry B. Higgins Professor of the Solid State, Emeritus
BERTRAM EUGENE WARREN, SC.D.
Professor of Physics, Emeritus; Senior Lecturer

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 ever widening 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 Department of Physics is aware of the vital importance of maintaining an active research program of the 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 practically every field of active interest. The facilities of these research programs are available to students in the Department of Physics.

In the fields of nuclear and elementary particle physics, there are available electronuclear machines capable of producing high-energy particles. These include a cyclotron, electrostatic generators and a linear accelerator. A major facility, the Cambridge Electron Accelerator, is operated under the joint auspices of Harvard and M.I.T. In addition to the research centered around these machines, there is active research in nuclear physics using, among others, the techniques of atomic beams and nuclear magnetic resonance, and there is an active program in applied radioactivity.

While M.I.T. has no astrophysics or astronomy departments as such, active research in these fields is being carried out in the Departments of Physics, Mathematics, Geology and Geophysics, and Electrical Engineering. Facilities and staff in one or more of these departments are available for research in theoretical astrophysics, radio astronomy, and theoretical and experimental studies of the interplanetary and interstellar medium. Several of these investigations have made use of earth satellites and deep space probes. Cosmic rays are studied both for their astrophysical implications and as a source of very high-energy particles. In addition to the facilities in Cambridge, M.I.T. now has apparatus operating in Bolivia and New Mexico.

A large and active program in atomic, molecular, plasma, and solid-state physics provides a student with unique opportunities for studies in these fields. Equipment is available for spectroscopic studies at radio, microwave, infrared and optical frequencies. Currently available are facilities for the production of low temperatures, high pressures, and magnetic fields up to 100,000 gauss. A magnet capable of producing a steady magnetic field of 250,000 gauss is available as one of the facilities of the Francis Bitter National Magnet Laboratory. Facilities for the study of matter using X-ray and neutron diffraction techniques are at hand. The 5,000 kw M.I.T. Reactor is used for neutron diffraction studies.

The extensive facilities of the Information Processing Services Center and of the Multiple Access Computer (Project MAC) are available for research that involves the use of high-speed computation.

Closely integrated with the experimental work, using the equipment mentioned, there are active groups studying nuclear, elementary particle, field, atomic, molecular, and solid-state theory.

Much of the research described above is carried out as part of the work of various interdepartmental laboratories, including the Laboratory for Nuclear Science, Research Laboratory of Electronics, Spectroscopy Laboratory, Center for Materials Science and Engineering, Center for Space Research, and the Education Research Center. These facilities provide close relationships among the research activities of a number of M.I.T. departments and give students the opportunity for contact with research carried out in disciplines other than physics.

THE UNDERGRADUATE CURRICULUM

Physics (Course VIII)

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 45–48.

In the second year it is suggested that the student take INTRODUCTORY NETWORK THEORY (6.01) or ELECTRONIC NETWORKS AND DEVICES (6.14) in the second term in order to acquire a familiarity with and a knowledge of some topics in electrical engineering. Adequate elective time is made available in the second year and students may wish to take a mathematics subject beyond 18.034 at this time.

The departmentally prescribed subjects 8.05, 8.13T, and 8.14T are normally taken in the third year and this is an appropriate time to take

some of the restricted elective subjects. It is usual to start the theoretical physics sequence with 8.06 in the second term of the third year. 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 the theoretical sequence is then continued with 8.07T and completed with 8.08T. 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 (8.15) 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 research is done by the professional physicist.

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 8.15 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 8.06, 8.07T and 8.08T are designed to recapitulate and organize the essentials of theoretical physics and also to provide a solid springboard for much of the student's future education in physics.

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

		Total units
GENERAL INSTITUTE REQUIREMENTS (*see page 195*)		
	Specific science and humanities and social science subjects	**128**
	The Science Distribution Requirement will be satisfied by 8.03T and 18.034, which are required in the Departmental Program, plus appropriate subjects[1] (see page 48) totaling	**12**
	The subject 8.13T, which is required in the Departmental Program, appears on the list of Laboratory Subjects (see page 49) and can be used to satisfy the Laboratory Requirement.	

DEPARTMENTAL PROGRAM

	Required Subjects				
18.034	DIFFERENTIAL EQUATIONS	3	0	9	
8.03T	PHYSICS III	5	0	7	
8.04	PRINCIPLES OF QUANTUM PHYSICS	5	0	7	
8.05	PHYSICS OF ATOMS AND MOLECULES	4	0	8	
8.13T	EXPERIMENTAL ATOMIC PHYSICS I	0	6	6	
8.14T	EXPERIMENTAL ATOMIC PHYSICS II	0	6	6	
8.15	EXPERIMENTAL PHYSICS	2	0	2	
	[2]THESIS		12		
					88
	Restricted Electives				
	Two subjects given by the Department of Mathematics beyond 18.034		24		
	Two subjects given by the Department of Physics in addition to those listed above[3]		24		
					48
	Unrestricted Electives[4]				**84**
Total units required for the S.B. degree					**360**

[1] Students may find it advantageous to elect 6.01 INTRODUCTORY NETWORK THEORY (4–0–8) or 6.14 ELECTRONIC NETWORKS AND DEVICES (4–2–6) in the second term of the second year. This would complete the Science Distribution Requirement.

[2] A thesis of 12 units is required. Not more than 30 units of thesis credit may be included in the minimum of 360 units required for the S.B. degree.

[3] Students planning to do graduate work in physics would normally take the theoretical sequence 8.06, 8.07T and 8.08T.

[4] Schedules of students in Course VIII may always be arranged to leave available 12 units of unrestricted elective in the second year.

GRADUATE STUDY IN PHYSICS

The Department of Physics offers graduate work leading to the degrees of Master of Science in Physics, Doctor of Philosophy, and Doctor of Science. 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 assistantships are available each year for graduate students. The duties of these assistants involve both the teaching and research activities of the Department. 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. Specifically, a

student intending to pursue graduate work in physics should have as a background the equivalent of the S.B. requirements for Course VIII, but some deficiencies may be removed while the student is engaged in graduate work.

The Graduate Degrees

The general requirements for graduate degrees are set forth in Section 3.

MASTER OF SCIENCE IN PHYSICS

For the Master of Science degree, a reading examination in scientific French, scientific German, or scientific Russian is required.

DOCTOR OF PHILOSOPHY AND DOCTOR OF SCIENCE

For the degree of Doctor of Philosophy or of Doctor of Science, the Department of Physics permits satisfying the language requirement from the following: 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.

Joint Doctoral Program in Oceanography with the Woods Hole Oceanographic Institution

The Woods Hole Oceanographic Institution and the Departments of Geology and Geophysics and of Meteorology offer a joint program of education and research in oceanography that leads to the degree of Doctor of Philosophy or Doctor of Science, awarded jointly by the two institutions. The program is administered by a committee drawn from the faculty and staff of the two institutions. The general requirements for the degrees are the same as those for the M.I.T. doctorates, given in Section 3. Students in this program may choose to specialize in marine geophysics, marine geology, marine chemistry or physical oceanography. A student will normally spend his first graduate year at M.I.T., his second year of course work at either or both institutions and do his thesis research at either institution depending on his research interests and the location of the appropriate facilities. The Woods Hole Oceanographic Institution operates a fleet of research ships and aircraft, has extensive laboratory facilities and a research staff active in all areas of oceanography. Extensive resources for advanced study and research in oceanography are available at M.I.T.; these are described in other parts of this Catalogue. A modest marine facility is maintained on Boston Harbor consisting of dock space, a staging area and a small research boat. These facilities are a useful supplement to the more complete resources at Woods Hole; they provide ready access to local ocean areas for students in residence at M.I.T.

Entrance Requirements for the Joint Program

Oceanography is not a separate scientific discipline but is a field in which the basic sciences and the methods of other earth sciences are used to explore the scientific problems of the waters and the floors of the ocean basins. All applicants must have a sound preparation in physics and the concomitant mathematics. Students who intend to specialize in marine geology or marine chemistry must have undergraduate preparation in geology and chemistry. Some undergraduate preparation in fluid mechanics or dynamic meteorology will prove advantageous to students interested in water motions. Such students are advised to take mathematics through advanced calculus. No previous academic work in oceanography is required.

THE GRADUATE PROGRAM

Subjects in oceanography are offered by the Departments of Meteorology and of Geology and Geophysics and by the Woods Hole Oceanographic Institution. These subjects are described in the Description of Subjects section of this Catalogue under Course XII, Geology and Geophysics and Course XIX, Meteorology. In addition several other M.I.T. departments offer subjects in the marine sciences or in areas basic to oceanography. Each student in the program will have an advisor or advisors who will help him to plan an academic program that is adapted to his interests. The program of academic subjects occupies the first two years of graduate study and serves to prepare the student for the General Examination. As a part of the General Examination, each student is required to submit and defend a thesis proposal.

The Graduate Degrees

The joint program leads to the degree of Doctor of Philosophy or Doctor of Science. The degree of Master of Science in Oceanography is offered by the Department of Geology and Geophysics and by the Department of Meteorology. Further information on this degree will be found on the pages devoted to these departments.

Assistantships and Fellowships

A limited number of fellowships and graduate assistantships is available on a competitive basis. Further information and applications may be obtained from the Heads of the Departments of Meteorology and of Geology and Geophysics and from the Dean of Graduate Studies of the Woods Hole Oceanographic Institution.

Application Procedures

Application for admission to the joint program should be made on the M.I.T. Graduate Application form, copies of which may be obtained from the Director of Admissions at M.I.T. or from the Woods Hole Oceanographic Institution. Requests for further information on the joint program may be addressed to the Head of the Department of Geology and Geophysics, the Head of the Department of Meteorology or the Dean of Graduate Studies of the Woods Hole Oceanographic Institution.

OTHER ACADEMIC DEPARTMENTS AND OFFICES

DEPARTMENT OF AEROSPACE STUDIES

GEORGE PAUL GAMACHE, M.S.
Major, U. S. Air Force
Professor of Aerospace Studies; Head of the Department

RICHARD EMORY BRUBAKER, M.S.
Major, U. S. Air Force
Associate Professor of Aerospace Studies

Instructors

WILLIAM ELIAS LEE
Technical Sergeant, U. S. Air Force

EARL SYLVESTER RASMUSSEN
Technical Sergeant, U. S. Air Force

CENTER FOR INTERNATIONAL STUDIES

MAX FRANKLIN MILLIKAN, PH.D.
Director

DONALD LAWRENCE MORTON BLACKMER, PH.D.
Assistant Director

DRAMA

JOSEPH DEE EVERINGHAM, A.M.
Director of Drama

INFORMATION PROCESSING SERVICES

RICHARD GWYN MILLS, S.M.
Director

INTERDEPARTMENTAL LABORATORIES

Center for Materials Science and Engineering

NICHOLAS JOHN GRANT, SC.D.
Director

HARRY CONSTANTINE GATOS, PH.D.
Associate Director

Center for Space Research

JOHN VINCENT HARRINGTON, SC.D.
Director

HERBERT SAGE BRIDGE, PH.D.
Associate Director

Francis Bitter National Magnet Laboratory

BENJAMIN LAX, PH.D.
Director

DONALD THOMAS STEVENSON, PH.D.
Assistant Director

ELMER WILBUR LAURENCE DAVIS, S.B.
Assistant Director for Administration

Laboratory for Nuclear Science

PETER THEODORE DEMOS, PH.D.
Director

FREDERIC JOHN EPPLING, PH.D.
Associate Director

Operations Research Center

PHILIP MCCORD MORSE, PH.D., SC.D.
Director

ALVIN WILLIAM DRAKE, SC.D.
Associate Director

Research Laboratory of Electronics

HENRY JOSEPH ZIMMERMANN, S.M.
Director

GEORGE GRAHAM HARVEY, PH.D.
Associate Director

SAMUEL JEFFERSON MASON, SC.D.
Associate Director

RALPH ALLEN SAYERS
Assistant Director

Spectroscopy Laboratory

RICHARD COLLINS LORD, PH.D., SC.D.
Director

Urban Systems Laboratory

CHARLES LESLIE MILLER, S.M.
Director

FRANK SIDNEY JONES, M.B.A.
Assistant Director

CAMBRIDGE ELECTRON ACCELERATOR OF HARVARD UNIVERSITY AND THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

KARL STRAUCH, PH.D.
Director

JOINT CENTER FOR URBAN STUDIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND HARVARD UNIVERSITY

DANIEL P. MOYNIHAN, PH.D.
Director

LLOYD RODWIN, PH.D.
Chairman of the Faculty Committee

DEPARTMENT OF MILITARY SCIENCE

MARSHALL O. BECKER, M.A.
Colonel, Infantry
Professor of Military Science; Head of the Department

EUGENE RILEY HUNTON, JR., B.A.
Major, Infantry
Associate Professor of Military Science

DAVID BARRETT SMITH, M.A.T.
Captain, Artillery
Associate Professor of Military Science

DAVID JOSEPH PAWELSKI, M.ED.
Sergeant Major, U.S. Army
Assistant Professor of Military Science

Instructors

HENRY LEO WHALEN
Master Sergeant, U. S. Army

LOUIS WILLIAMS, JR.
Staff Sergeant, U. S. Army

Administrative Assistant

ROBERT CARMEN TOCCI
Specialist Five, U.S. Army

MUSIC

KLAUS LIEPMANN
Director of Music

JOHN DEAN CORLEY, JR., M.MUS.
Assistant Director of Music

GREGORY TUCKER
Director of M.I.T. Humanities Series and Chamber Music at M.I.T.

DAVID MAYER EPSTEIN, PH.D.
Conductor of the M.I.T. Symphony Orchestra

JOHN SANFORD OLIVER, M.MUS.
Assistant Director of the Glee Club

JOHN COOK, MUS.B.
Organist

DEPARTMENT OF NAVAL SCIENCE

DEAN ALDEN HORN, S.M.
Captain, U. S. Navy
Professor of Naval Science; Head of the Department; Professor of Naval Construction

JOSEPH ALLEN MATTHEWS, S.M.
Commander, U. S. Navy
Associate Professor of Naval Science

ORVAL FOWLER THORSON, III, M.A.
Lieutenant, U. S. Navy
Assistant Professor of Naval Science

Instructors

ROBERT ANDREW ERICKSON
Chief Yeoman, U. S. Navy

ROBERT GRANT MELLEN
Gunnery Sergeant, U.S. Marine Corps

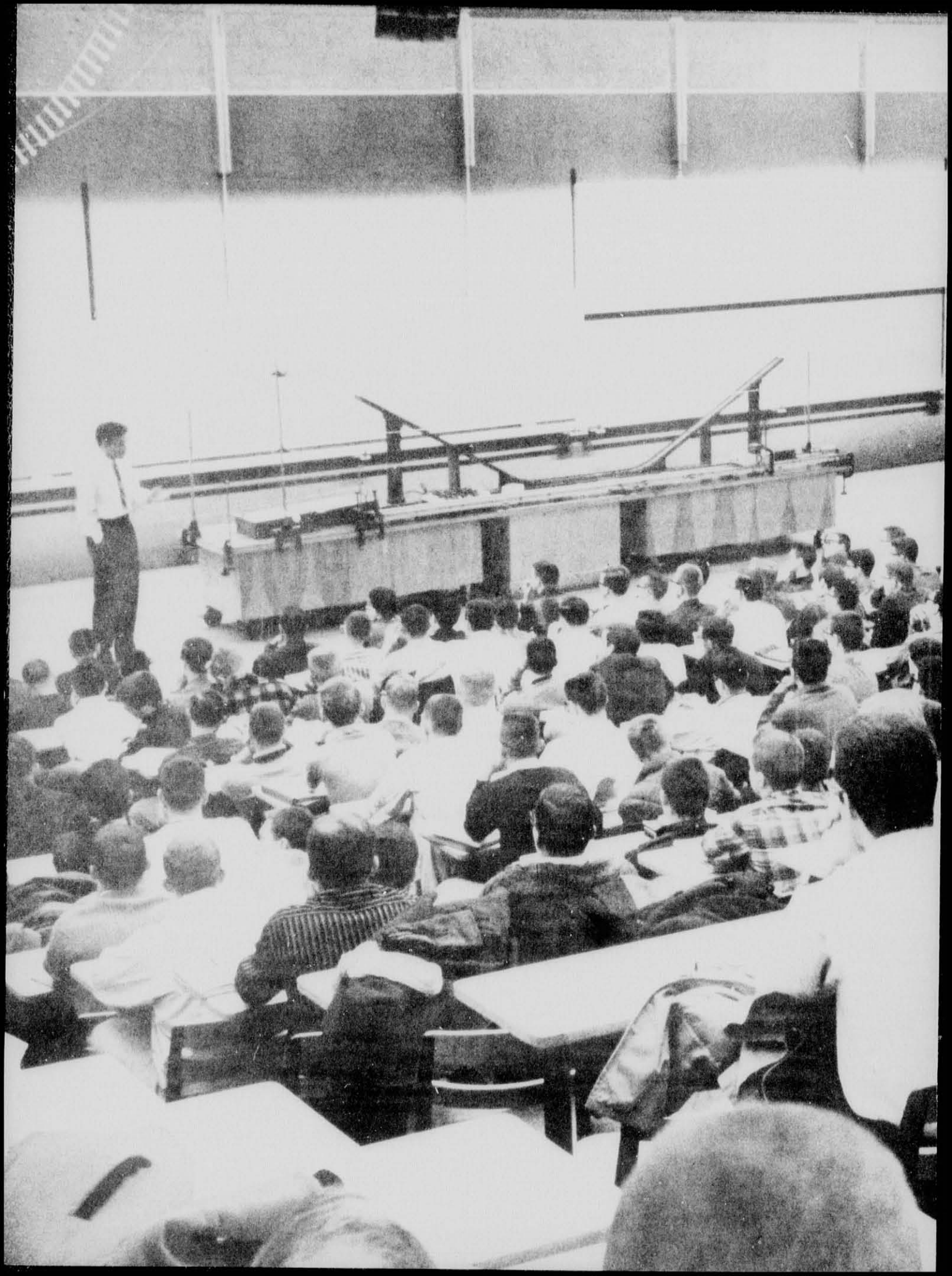
TERRY L. WARD
Yeoman First Class, U. S. Navy

CHARLES VIRGIL WEAVER
Chief Storekeeper, U.S. Navy

VISUAL ARTS

WAYNE VESTI ANDERSEN, PH.D.
Director of Exhibitions

GYORGY KEPES, M.A.
Director of the Center for Advanced Visual Studies



DESCRIPTIONS OF SUBJECTS

The subjects and descriptions given in this Section are subject to change. The final list of subjects to be given in 1968–69 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. Prerequisites may be waived by the instructor in charge, for particularly well qualified students.
2. The year classification (and term in which the subject is normally scheduled). "U" is an undergraduate subject; "G" is a subject given primarily for graduate students.
3. The time distribution of the subject, showing in sequence the units allotted to: recitation and lecture; laboratory, design, or field work; and preparation. Each unit represents 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 design 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 Engineering

1.00 *Information Systems*
Prereq.: ——
Year: U (1, 2) 3–3–6
Introduction to computer-based systems for the acquisition, processing, storage, retrieval, display, and transmission of engineering information. Basic principles of programming systems and languages. Man-machine communications, input/output design, organization of computer systems. Introduction to the design and applications of problem-oriented languages and integrated systems. Real-time systems, computer-aided design, graphical data processing, and the role of information systems in engineering organizations. Extensive laboratory experience in computer programming and the application of information systems to civil engineering problems. (*Primarily for undergraduates in Courses* I, XV[2, 4]; *others admitted by permission of instructor.*) *Roos*

1.01 *Engineering Mechanics*
Prereq.: 8.01, *18.02*
Year: U (1) 4–0–8
Static behavior of rigid and deformable bodies with primary emphasis on deformable systems. Equilibrium conditions for a rigid body. Statical determinancy and indeterminancy. Force analysis of statically determinant systems. Introduction to the analysis of deformable bodies. Application to systems involving only uniaxial deformation. Analysis of stress and strain at a point. Discussion of stress-strain relations. Stresses and deflections of beams due to bending. Analysis of statically indeterminate beams. Introduction to elastic stability. *Connor*

1.02 *Engineering Materials*
Prereq.: 8.01
Year: U (1, 2) 3–3–6
Principles underlying the structure-properties interaction in materials important to civil engineers. Topics including atomic arrangements in crystalline and non-crystalline phases; thermodynamics of phase relationships and structural change; elasticity, microplasticity, viscoelasticity, and fracture; corrosion. Application of principles to structural metals, cementitious materials, structural ceramics, wood, asphalt, and polymers. Mechanical properties of composite materials, including Portland cement concrete, asphalt-aggregate mixtures, and reinforced plastics. Laboratory work on the common techniques used in the study of microstructure and in the determination of mechanical properties. (*Fall term — recommended for Course* IV *Students. Spring term — recommended for Course* I *students.*) *Jones, Williamson*

1.03 *Engineering Analysis*
Prereq.: 18.034
Year: U (1) 4–0–8
Mathematical formulation of engineering problems, solutions and physical interpretation of results. Examples illustrating use of ordinary differential equations are chosen largely from dynamics. Essentials of dynamical principles established via vectors. Concepts of constraints, degree of freedom. Introduction to Lagrange's equations. Free and forced vibrations, damping. Boundary value problems in structural theory. Eigenfunctions introduced through vibration and buckling of beams and columns. Fourier Series, Bessel functions. Introduction to partial differential equations by separation of variables. *Mei*

1.04 *Structural Analysis and Design I*
Prereq.: 1.01
Year: U (1) 3–3–6
The analysis of determinate and indeterminate structural systems and the design of structural elements. Particular emphasis on indeterminate systems and on the relation between the behavior of a member and the criteria pertinent to its rational design. Basic force-deformation relationships for member elements. Discussion of equilibrium, compatibility, and stress-strain equations. The force and displacement methods for solution, including superposition, slope deflection, and moment distribution. Formulation of the matrix equations for pin-connected trusses. Solution techniques using the stiffness method. Techniques for the approximate analysis of large framed structures. Contemporary design criteria and practice for the design of steel elements, trusses, and rigid frames. (*See also 1.51*) *Biggs*

1.05 *Fluid Dynamics*
Prereq.: 1.01, *1.03*
Year: U (1) 3–3–6
The fundamental principles and methods of fluid dynamics for Newtonian compressible and incompressible fluids. Fluid continua and their properties; kinematics and rotating coordinate systems. Conservation equations for mass, momentum, and energy. Stress-strain relations, leading to the development of the Navier-Stokes equations for three-dimensional laminar fluid motions. Introduction to stream functions and velocity potentials. Dynamic similitude and basic concepts of creeping motions, flow in porous media, boundary layers, turbulence, and turbulent shear stresses. Flow and energy dissipation in uniform conduits. Design of pipe line systems. Lectures supplemented by laboratory experiments and projects. (*See also 1.60.*) *Harleman*

1.06 *Soil Mechanics*
Prereq.: 1.01
Year: U (2) 3–3–6
The fundamental principles of stress-strain behavior, with applications to retaining walls, foundations, and slope stability problems. Composition and structure of soils; phase relationships and unit weights; interactions between mineral particles and water; classification systems; transmission of forces between mineral particles. Influence of pore pressure upon strength and compressibility; effective stress; effect of flowing water upon stability. Pore pressures induced by loadings; drained and undrained strength; theory of consolidation. Principles of limit analysis for soil masses. Methods for estimating deformations of soil masses. Project-type laboratory exercises emphasizing applications of principles to practical problems. *Bromwell*

1.07 *Analysis of Uncertainty*
Prereq.: 18.034
Year: U (2) 3–1–5
Introduction to probabilistic methods in civil engineering. Formulation and analysis of stochastic models of

engineering systems and their environment, including estimation of the models' parameters and measures of the models' quality. Elementary notions of probability including events, random variables, expectation, and derived distributions. Common distributions as models of physical phenomena. Simple time-dependent processes. Statistical treatment of experimental data. Elementary theory of decision making under uncertainty, including classical hypothesis testing. Examples and problems drawn from practice and literature in structures, transportation, materials, water resources, and soils. *Cornell*

1.08 *Geotechnology*
Prereq.: ——
Year: U (1) 3–3–6
Basic principles of physical geology, with emphasis on topics pertinent to civil engineering. Minerals. Igneous, metamorphic and sedimentary rocks. Alluvial, glacial, eolian, lacustrine, marine, and colluvial sediments. Weathering. Rock defects. Earthquakes. Airphotos and geologic maps. Field trips. *Hirsch 'd*

1.09 *Civil Engineering*
Prereq.: 1.04, 1.05, 1.06, 1.07, 1.08
Year: U (2) 0–6–12
Introduction to formulation and solution of civil engineering problems. Design and decision making in civil engineering practice. Relationship of theoretical and experimental approaches in practical problem solving. Economic, political, social, and legal constraints and factors which influence engineering decisions. Problems of uncertainty and incomplete data. Consideration of performance, reliability, and failure factors in engineering design. Feasibility studies, planning, and organization of engineering projects. Development of a series of case studies based on actual civil engineering projects drawn from professional experiences of the senior faculty of the Department. *Whitman*

1.10 *Civil Engineering Laboratory*
Prereq.: ——
Year: U (1, 2) 0–6–6
A program designed to introduce the student to the experimental solution of problems in the major disciplines of civil engineering. Students work on two or three experimental projects, each in a different laboratory of the Department. *Ippen*

1.141 *Numerical Methods of Engineering Analysis I*
Prereq.: 18.034
Year: G (1) 3–0–6
Review of linear algebra. Vector space. Linear dependence. Matrix notation and operations. Solvability of linear algebraic equations. Quadratic forms. Characteristic value problems. Computational techniques for linear algebraic equations, exact and iterative methods, operational counts, partitioning techniques. Computational techniques for discrete characteristic value problems, iterative and exact methods. Solution of non-linear algebraic and transcendental equations. *Christian*

1.142 *Numerical Methods of Engineering Analysis II* (A)
Prereq.: 1.141
Year: G (1, 2) 3-0-6
Discrete linear operators. Interpolation, numerical integration, and differentiation. Least squares approximations, orthogonal functions. Solution of second-order partial differential equations by separation of variables. Application to specific problems. Use of variational techniques in the treatment of boundary conditions. Approximate solutions of differential equations. Initial and boundary value problems. Boundary and interior methods. Finite difference techniques. Error minimization techniques. *Staff*

1.143 *Mathematical Optimization Techniques I* (A)
Prereq: 1.00, *1.141*
Year: G (1) 3–0–6
Systematic survey of theory and applications of mathematical optimization techniques to problems encountered in the analysis, synthesis and operation of engineering systems. Formulation of optimization models for engineering problems. Solution techniques for classes of models. General techniques — brief review of linear algebra, emphasis on duality theory as a central approach to linear programming theory and algorithms. Special techniques — primal and dual simplex, complementary pivot, primal-dual, upper-bounding techniques and post-optimality problems. Introduction to graph theory, network flow algorithms. Introduction to non-linear programming. Computation — emphasis on application and use of simplex method and its variants as the core of an integrated computer system for linear and non-linear programming. Experience in computer programming of optimization algorithms. *Hershdorfer*

1.144 *Mathematical Optimization Techniques II* (A)
Prereq.: 1.143
Year: G (2) 3–0–6
Continuation of 1.143. Formulation of discrete and non-linear programming models for engineering problems. Solution techniques for discrete problems (cutting-plane methods, partitioning methods, branch and bound) and for non-linear problems (separable programming, direct search techniques for unrestricted and restricted, univariate and multivariate problems, geometric programming). Comprehensive study of stochastic programming problems and solution techniques (expected value problems, Dantzig's two-stage approach, chance-constrained approach, minimal variance). Computation — emphasis on applications and use of an integrated computer system for discrete and non-linear programming. *Hershdorfer*

1.146 *Elements of Systems Analysis* (A)
Prereq.: 1.07, *1.143*, 14.02
Year: G(1) 3–0–6
Developments of integrated procedures for the identification, definition and selection of optimal systems. Formulation of the design of complex systems as a multi-dimensional problem in resource allocation among a spectrum of technically acceptable alternatives. Classical analysis techniques: production functions; marginal analysis; tradeoffs between system configurations. Special treatment of the impact of computers on the scope and techniques of engineering analysis. Mathematical programming for the identification of desirable design characteristics, the definition of least cost mixes, and the optimization of systems with time-dependent benefits and costs. Application of risk strategies and statistical decision theory to planning under uncertainty. Modeling of system interactions through simulation and other techniques. Current use of benefit/cost and cost/effectiveness analysis in engineering practice. Detailed study of specific designs in the fields of transportation, water resources, structures and others of interest to the students. (*Special sessions for Practicing Engineers in the Center for Advanced Engineering Study*). *de Neufville, Stafford*

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1.147 ***Engineering Systems Analysis*** **(A)**
Prereq.: 1.146
Year: G (2) 3–0–6
Methods for the design of large-scale systems with full recognition of the implications of the economic and social environment. Integration of the principles of systems analysis by intensive examination of proposed projects. Definition of policy objectives and their effect on engineering design and public works investment policies. Identification and measurement of benefits. Use of statistical inference for the prediction of the demand for facilities and of the differential impact of alternative designs. Analysis of demand-supply equilibrium to determine optimal tolls and to minimize costs by designing for market stability. Use of computer-aided design procedures in the search for and choice of optimal systems. (*Special sessions for Practicing Engineers in the Center for Advanced Engineering Study*).
de Neufville, Stafford

1.148 ***Decision Theories in Engineering and Planning*** **(A)**
Prereq.: 1.07 or 1.143 or 1.146
Year: G (2) 3–0–6
Prescriptive decision theories and limitations in applying them to real engineering and planning problems. Primarily from the point of view of urban and regional planning and such engineering areas as transportation and water resource planning. Development of general concept of a Problem Solving Process, including Search, Prediction, Evaluation, Choice and other component activities. Definitions of, and limitations on, rationality; subjective probabilities and Bayesian decision theory; relaxation of information requirements in applying Bayesian decision theory in practical situations; sequential decision models; economic analysis of systems; problems of generating alternatives; Alexander's methods for structuring the search process; hierarchical structure; economics of problem solving. Research seminar with extensive student contributions. Advanced subjects in psychology, political science, economics, planning, or selected other areas may be accepted in lieu of prerequisites.
Manheim

1.151 ***Computer Approaches to Engineering Problems***
Prereq.: ——
Year: G (1) 3–2–4
Introduction to computer systems and programming languages. Engineering applications of programming languages. Man-machine communication, problem-oriented languages and integrated systems for their development and use. Computer-aided design. Modular and dynamic computer systems and languages for dynamic data structuring and program management and for language definition. Survey of computer hardware and software and their use in civil engineering, graphics and time-sharing systems. Extensive laboratory experience in computer programming and project application of information systems to civil engineering problems. (*Primarily for Course I graduate students: others admitted by permission of instructor.*)
Roesset

1.152 ***Engineering Computer Systems Design*** **(A)**
Prereq.: 1.00 or 1.151
Year: G (2) 3–2–4
System programming considerations in the design of engineering computer systems. Operating systems; engineering programming languages; generation and processing of problem oriented languages; engineering data structures; program structures; management of primary and secondary storage. Planning and implementing prototype engineering computer systems. Laboratory experience in system programming using IBM System/360 assembly language.
Logcher

1.153 ***Engineering Computer Management and Use*** **(A)**
Prereq.: 1.00 or 1.151
Year: G (2) 4–0–5
Implications of the computer in engineering problem solving. The use of the computer in engineering design, construction, and management. Engineering information systems and real-time engineering systems. The implementation and use of computers by engineering organizations — hardware, software, operational, economic and organizational considerations. Several seminars by qualified outside speakers. (*Enrollment limited, undergraduates accepted only by permission of instructor.*)
Roos

1.154 ***Simulation Methods*** **(A)**
Prereq.: 1.00 or 1.151 or 1.156; 1.07 or 6.28 or 6.579
Year: G (2) 3–0–6
Application of simulation to the solution of engineering problems. Development of the theory of simulation methods. Generation of random numbers, transformation, hypothesis testing, variance reduction techniques, sampling theory, and experimental design. Discussion and use of computer simulation languages. Formulation and programming of simulation models. Applications of these models in the analysis, design, and operation of specific systems.
Sussman

1.156 ***Computer Systems***
Prereq.: ——
Year: G (1) 2–1–6
Basic components of a computer system. Computer programming, including programming languages, organization and planning of programs. Man-machine communication, time sharing (including student use of a time-sharing system). Design and use of problem-oriented languages. Role of graphical input-output. Operating Systems. Dynamic Memory Allocation. Comparisons between computer systems. Impact of the computer on Engineering. (*Restricted to Practicing Engineers in the Center for Advanced Engineering Study.*)
Perkins, Sussman

1.16J ***Special Studies in Systems Engineering*** **(A)**
(Same subject as 2.191J, 6.604J, 13.47J)
Prereq.: 1.00, 1.143
Year: G (2) 2–4–6
Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — An integrated urban transportation system; Group 2 — A manned satellite inspection and retrieval system.)
de Neufville, Baumann, Seifert, Frankel

1.18 ***Building Design Systems*** **(A)**
Prereq.: 1.152
Year: G (1) 3–2–4
Application of advanced computer systems concepts to the modeling of buildings for analysis and evaluation in building design. This field includes: Survey of existing techniques for design synthesis of building systems. Problems of maintaining a computer representation of the current state of the building design. Organization of building description according to component systems. Data structures for describing building geometry. Computational algorithms for building systems evaluation.

Data transfer among evaluative routines. Development of a building design data library. Role of problem-oriented languages and interactive input-output devices. Team design via multiterminal systems. *Hershdorfer*

1.19 *Urban Systems Analysis Techniques* (A)
Prereq.: ——
Year: G (2) 3–0–6
Investigation of the application of information processing and systems analysis to methods of dealing with urban problems. Emphasis on the translation of general criteria into specific programs, with applications via case studies. Structuring of problems to isolate quantifiable and judgmental components. Topics selected from the following: use of computers for urban data storage and retrieval and for the application of mathematical optimization, cost-effectiveness analysis, program budgeting, and other systems analysis techniques; design of information systems for specific urban planning and design applications; problems involved in the integration of independent information systems. (*Primarily for advanced graduate students with background and interests in urban problems.*) *Hershdorfer*

1.201 *Transport Systems Analysis I* (A)
Prereq.: ——
Year: G (1) 3–0–6
Introduction to the transport systems problem: system components, functions of transportation, demand patterns, types of transportation problems. A framework for analysis: decision makers and their options, social and economic impacts of transportation, the prediction problem, the decision problem. Transportation technology: basic physics of transportation, major technologies, the spectrum of alternative technologies. Some basic transportation problems: urban, megalopolitan transportation; transportation and economic policy. The analysis process: basic types of models, parametric analysis, other techniques; examples: urban transportation planning, VSTOL for the Northeast Corridor. (*Primarily for incoming graduate students with diverse backgrounds.*) *Manheim*

1.202 *Transport Systems Analysis II* (A)
Prereq.: 1.143, 1.146, 1.201
Year: G (2) 3–0–6
Techniques for the analysis of multimode transportation systems. Demand models for freight, passenger movements. Modeling line-haul and collection-distribution systems for various modes; general models of transportation technology. Supply functions. Predicting the equilibrium of supply and demand in transportation networks: traffic assignment, optimal flow, routing and scheduling and other techniques. Predicting the impacts of transportation on the social, economic, and political environment. Evaluation of transportation alternatives: costing; evaluating indirect and intangible impacts. *Manheim*

1.203 *Transport Systems Analysis III* (A)
Prereq.: 1.148, 1.151, 1.202
Year: G (1) 3–0–6
The transportation planning process. Options and objectives in transportation. Typical transportation study environments: urban, regional, developing country. Search techniques: network generation, land use plan design, optimal scheduling, etc.; tradeoff analysis; capital budgeting. Evaluation and choice: utility theory and scale construction, evaluation of non-economic impacts. Uncertainty: decision theory, flexibility, evolutionary planning techniques. Information acquisition: sampling, monitoring flows, data systems. Allocation of analysis resources: hierarchical structure, critical-path, etc. Organization of the planning process: theory, practice. Interaction of analysis with the political process. Case study. Student papers. *Staff*

1.212 *Urban Transportation Systems* (A)
Prereq.: 1.201
Year: G (2) 3–0–6
Techniques for planning and programming large-scale urban transportation systems. Estimation of traffic demand and its distribution to facilities utilizing mathematical models and computer programs. Analysis and design of system components and control systems. Measures of effectiveness of alternate schemes. Applications to specific projects. *Staff*

1.221J *Flight Transportation* (A)
(Same subject as 15.483J, 16.751J)
Prereq.: 1.201
Year: G (1) 3–0–6
Integrated discussion covering basic concepts and operational characteristics of flight transportation systems. Methods of predicting vehicle performance, anticipating future design trends, and determining direct operating costs; airport design and functional layout; guidance and control techniques, both in terminal area and en route; communication and radar system performance. *Bone, S. Myers, R. H. Miller*

1.222J *Flight Transportation Seminar*
(Same subject as 15.484J, 16.752J)
Prereq.: ——
Year: G (1) 1–0–2
Economics of airline operation, problems of financing and of domestic and international route allocation. Subject developed around seminars presented by speakers from the regulatory agencies, national and international organizations, and industry on particular phases of flight transportation. Preparatory lecture preceding each seminar. Opportunity for students to conduct studies in their area of major specialization on a particular topic covered by the subject. *Bone, S. Myers, Browne*

1.23 *Flight Transportation Facilities* (A)
Prereq.: 1.201 or 1.221J
Year: G (2) 3–0–6
Basic requirements of an airport system, including air traffic control, airfield layout, terminal functional design, parking facilities, and ground transportation. Consideration of aircraft requirements, present and future; air traffic potentials; protection of runway approaches; and influence on aircraft operation of airport environs. Development of an airport master plan; runway, taxiway, and apron layouts; parking, drainage, and lighting systems. Site planning of terminal area, including access roads, parking lots, loading areas, and terminal building space requirements. Circulation systems for passengers and cargo, airline operations, and apron activities. Airport administration and finance. *Bone*

1.251 *Theory of Traffic Flow* (A)
Prereq.: 1.07
Year: G (2) 3–0–6
The fundamental diagram of discrete-flow processes with distributed velocities. Fluid-flow analogies, shock waves, and damped oscillatory models of car-following behavior, characterization of a flow stream in terms of headway distributions, and derivation of associated counting laws. Operations on streams involving entry and crossing criteria with derivation of the resulting virtual renewal process leading to formulation of queuing models for study of delay, inventory, and other important stochastic processes. Applications to road, air, and rail traffic system design. *Staff*

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1.258 ***Case Studies in Transportation Engineering*** **(A)**
Prereq.: 1.201
Year: G (2) 3–0–6
Techniques for the planning and design of components of transportation systems. Measures of effectiveness of alternate schemes. Applications to specific projects in fields of highway, traffic control, public transit or airport engineering. *Bone*

1.261 ***Advanced Transportation Planning I*** **(A)**
Prereq.: 1.203
Year: G (1) 4–2–9

1.262 ***Advanced Transportation Planning II*** **(A)**
Prereq.: 1.261
Year: G (2) 4–2–9
Integration of technical tools in concerted attack on a specific major transportation problem, such as development of a transportation plan for a U. S. metropolitan area or for a major region in a developing country. Review of transportation planning techniques and related methodologies: economic analysis, socio-economic impacts of transportation, demand models, network models, vehicle performance prediction, analysis of uncertainty, etc. Discussion of substantive issues of transportation policy, in general and in the specific problem context: goals in transportation planning, tradeoffs among technologies, technological innovations, problems of consumer preferences. Student work individually and in groups to resolve specific policy questions through technical analyses. Emphasis on the critical analysis of present transportation planning methods, on the development of improved approaches, and on the ability to adapt approaches to data limitations, political considerations, and other substantive realities. *(Primarily for advanced students in transportation. Permission of instructor required.)* *Manheim*

1.27 ***Special Studies in Transportation Engineering*** **(A)**
Prereq.: 1.201
Year: G (1 or 2) *Arr.*
Advanced study of a topic in transportation systems selected with the approval of the instructor. *Staff*

1.311 ***Theoretical Soil Mechanics I*** **(A)**
Prereq.: 1.06
Year: G (1) 3–0–6
Discussion of elementary theories important in soil mechanics. Theories of elastic halfspace and elastic layers. Applications of elastic theories, especially to settlement problems. Use of limit analyses for active and passive stresses, bearing capacity, and slope stability. Theory of consolidation for one-dimensional problems and introduction to three-dimensional consolidation. Mathematics, construction and interpretation of flow nets. *Christian*

1.312 ***Theoretical Soil Mechanics II*** **(A)**
Prereq.: 1.311
Year: G (2) 3–0–6
Content variable from year to year. Such topics as advanced problems in three-dimensional consolidation; Kotter's equation; modern earth pressure theories of Brinch Hansen and Sokolovski; theories of plasticity applied to soil systems. *Christian*

1.321 ***Soil Behavior*** **(A)**
Prereq.: 1.361
Year: G (2) 3–0–6
Detailed study of soil properties with emphasis on methods of measuring properties in the field and laboratory and interpretation of experimental data for use in practice. Topics include: consolidation behavior of clays; basic strength principles; stress-strain behavior of saturated clays, emphasizing the influence of sampling, different types of stress systems, and environment; strength and compression of granular soils; engineering properties of compacted clays; permeability and capillarity. *Ladd*

1.322 ***Soil Technology*** **(A)**
Prereq.: 1.06
Year: G (1) 3–0–6
Application of physico-chemical principles to an understanding of the engineering behavior of clay soils. Structural chemistry, clay mineralogy, chemical weathering, colloid chemistry, properties of adsorbed water, soil fabric, mineral friction. Emphasis on the use of fundamental principles in the interpretation and prediction of engineering properties such as permeability, compressibility, and shear strength. *Bromwell*

1.331 ***Soil Dynamics*** **(A)**
Prereq.: 1.06
Year: G (1) 3–0–6
Design of foundations for machinery; effects of earthquakes upon structures and earth dams, and ground motions caused by explosions. Stress-strain behavior of soil during transient and repeated loadings; relation of soil properties to wave velocity. Theory of wave propagation and dynamics of lumped systems as applied to problems in soil dynamics. *Whitman*

1.361 ***Advanced Soil Mechanics*** **(A)**
Prereq.: 1.06
Year: G (1) 3–0–6
Consideration of the following fundamentals of soil mechanics: the nature of soil, including a description of soil particles and stress transmission between particles, effective stress concept; fluid flow and its effect on soil behavior; stress-strain behavior of soil: lateral earth stresses and earth retaining structures; earth slopes; settlement and stability analyses of foundations and earth slopes. *Ladd*

1.362 ***Earth Structures*** **(A)**
Prereq.: 1.361
Year: G (2) 3–0–6
Design of earth dams and embankments including site exploration, excavation and drainage, stability and seepage, specifications, and construction control. Field measurements of settlement, horizontal deformations, pore pressures, and seepage. Case studies. *Hirschfeld*

1.364 ***Foundations*** **(A)**
Prereq.: 1.361
Year: G (2) 3–0–6
Foundations and earth retaining structures including considerations of shallow foundations, deep foundations, and braced excavations. Subject built around case studies involving exploration, laboratory and field tests, analyses, and the measurement of field performance. *Lambe*

1.37 ***Experimental Soil Mechanics*** **(A)**
Prereq.: 1.06
Year: G (1) 2–4–3
Laboratory determination of soil properties emphasizing experimental techniques. Topics include: classification of soils; oedometer tests with measurements of pore pressure dissipation; undrained strength of clays from vane and unconfined tests; drained and undrained shear tests with pore-pressure measurements employing triaxial, simple shear, or plane strain equipment; strength-volume change-permeability characteristics of compacted clays; special topics of interest to students, such as frost heave, capillarity, stabilization, or thixotropy. *Wissa*

1.38 *Engineering Geology* (A)
Prereq.: 1.06, 1.08
Year: G (2) 3–0–6
Geologic aspects of subsurface exploration, dams, reservoirs, foundations, slopes, tunnels and transportation systems, with emphasis on case studies. (*Alternate years. Not offered 1968–69.*) *Hirschfeld*

1.381 *Rock Mechanics* (A)
Prereq.: 1.06, 1.08; or 12.231, 12.271T
Year: G (2) 3–0–6
Principles of rock mechanics applicable to civil engineering. Engineering classification of rock. Field exploration. Stress distribution. State of stress in the earth's crust. Permeability, deformability, and strength of intact rock and rock masses. Introduction to applied rock mechanics — excavation, underground openings, slopes, foundations of heavy structures, rock reinforcement, field instrumentation. (*Alternate years.*) *Hirschfeld*

1.39 *Special Studies in Soil Engineering* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For graduate students desiring further study of special topics. *Staff*

1.40 *Introduction to Electron Microscopy*
Prereq.: ——
Year: U (1, 2) 1–3–2
Introduction to electron scattering and electron optics. Emphasis on student use of electron microscope for transmission and diffraction studies. Principles of operation. Preparation of specimens. Thin-film and replica techniques. Analysis and interpretation of micrographs and diffraction patterns. Supplementary use of optical microscopy. Application to study of structure of solid materials: metals, ceramics, glasses, polymers. Introduction to X-ray diffraction. *Williamson, R. C. Jones*

1.401 *Physics of Materials*
Prereq.: ——
Year: U (1) 3–0–3
Properties of bulk matter as related to atomic and molecular considerations. Kinetic theory of gases. The liquid state. Nature of bonding in liquids and solids. Amorphous and crystalline solid states. Types of crystals and characteristics. Concepts of elasticity, plasticity and fracture of solids. Demonstrations and laboratory exercises to illustrate principal topics. *Williamson*

1.41 *Strength of Structural Materials* (A)
Prereq.: 1.02
Year: G (1) 3–0–6
Detailed examination of strength theories applicable to structural materials. Analysis of failure criteria and phenomena: creep, yield, plastic flow, crack initiation and propagation, fracture mechanics. Effects of combined stress, loading rate, temperature, environment, radiation exposure. Ferrous and non-ferrous metals, cementitious materials, composites, timber, expanded substances, ceramics. *McGarry*

1.42 *Structural Materials* (A)
Prereq.: 1.02
Year: G (2) 3–2–4
Mechanical behavior of important materials in civil engineering structures. Principles relating composition and structure to such behavior. Emphasis upon basic factors to facilitate understanding and use of new materials and combinations. Elastic, plastic, viscoelastic, and other time-dependent types of deformation. Influence of defects and imperfections. Consideration of creep and fracture phenomena, adhesion and corrosion, composites and multiphase systems. Reference to present and anticipated materials. Laboratory primarily concerned with structure-composition-mechanical property interactions. *R. C. Jones*

1.43 *Structural Properties of Metals* (A)
Prereq.: 1.02
Year: G (1) 3–0–6
Engineering properties of structural metals. Structure, alloying, and the production of metals. Strengthening mechanisms and heat treatment. Mechanical properties of structural steels, reinforcing steels, cast and wrought iron-carbon alloys, and aluminum alloys. Forming, fabrication, and joining by welding or high-strength bolting. Design, preparation and properties of composite metals. Effect of environment on the properties of metals. Field trips to production, fabrication and heat treating facilities. *R. C. Jones*

1.44 *Cementitious Materials*
Prereq.: 1.02
Year: G (1) 3–0–6
Detailed study of cementitious materials with particular emphasis on the physical aspects of Portland cement and other hydraulic cements. Synthesis of elementary physical phenomena such as interlocking, chemical or phase changes, dimensional changes into the over-all reactions associated with binding materials. The nature of surfaces, absorption and adhesion with emphasis on the dependence of mechanical properties of the resulting microstructure. Laboratory demonstrations of surface forces, adhesion and hydration of Portland cement. Experimental techniques of investigating cementitious materials including peel tests, X-ray diffraction and electron microscopy. *Williamson*

1.45 *Structural Design of Pavements* (A)
Prereq.: 1.02, 1.06
Year: G (1) 3–0–6
Pavement types and wheel loads. Stresses in flexible and rigid pavements. Principles of engineering design of flexible and rigid pavements for highways and airfields. Detailed study of properties of highway materials. Discussions of environmental effects. Evaluation and strengthening of existing pavements. *Moavenzadeh*

1.46 *Portland Cement Concrete* (A)
Prereq.: 1.02
Year: G (2) 3–2–4
Advanced study of Portland cement concrete. Emphasis on mechanical behavior and durability as related to composition of binders, type and quantity of aggregates, nature of hardening. Creep, fracture mechanisms, and fatigue. *Moavenzadeh*

1.47 *Mechanics of Materials* (A)
Prereq: 1.02
Year: G (1) 3–0–6
Mechanical equation of state for engineering materials. Concepts of stress and strain. Isotropy, rate dependence, temperature effects. Elasticity, viscosity, plasticity, viscoelasticity. Applications to engineering analysis and design. *Moavenzadeh*

1.471 *Mechanical Behavior of Plastics* (A)
Prereq.: 1.02
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 research. *McGarry*

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1.472 ***Composite Materials*** **(A)**
Prereq.: 1.42
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 research. *McGarry*

1.473 ***Viscoelasticity*** **(A)**
Prereq.: 1.02
Year: G (2) 3–0–6
Methods of analysis of viscoelastic phenomena. Discrete element models, continuous distribution spectra. Constitutive equations for representation of viscoelastic behavior. Creep, relaxation, dynamic analyses. Principles of correspondence, interconversion, superposition. Treatment of non-linear systems. Applications to structural elements composed of metals, concrete, asphalt, soils. (*Alternate years.*) *Moavenzadeh*

1.48 ***Special Studies in Materials*** **(A)**
Prereq.: 1.42
Year: G (1, 2) *Arr.*
Advanced study, research, and laboratory investigations in the field of materials engineering. Arrangement of individual and group study of topics by the instructor in charge. Special reading assignments, consultation, and original investigations in the Materials Research Laboratory. *McGarry*

1.501 ***Naval Structural Analysis I***
Prereq.: 1.01 or 2.01
Year: G (1) 3–1–6
Analysis of determinate and indeterminate structural systems using classical techniques (virtual work, moment area, Castigliano's theorems, slope deflection, moment distribution, matrix analysis of pin-jointed trusses.) Approximate analysis techniques and plastic analysis also discussed. Development of proper perspective of analysis and design by consideration of simple structural design problems. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Mirabelli*

1.502 ***Naval Structural Analysis II***
Prereq.: 1.501
Year: G (2) 3–0–5
Introduction to the matrix displacement method for structural member systems. Analysis of curved beams. Elementary treatment of plates and shells and of buckling and dynamic response of structures. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Pahl*

1.51 ***Structural Analysis and Design***
Prereq.: 1.04, 18.034
Year: U (2) 3–2–5
Matrix displacement method for member systems. Analysis of curved beams and also variable depth members. Small deflection theory of plates. Elastic and inelastic stability of columns. Dynamic behavior of simple structural systems. Design of reinforced concrete beams, columns, slabs, and framing systems. Introduction to design of prestressed concrete. *Pahl*

1.521 ***Model Laboratory for Structural Design*** **(A)**
Prereq.: 1.04
Year: G (1) 2–3–4
Lectures, assigned reading, and laboratory covering the theory and practice of model analysis to facilitate the analysis and design of structures and structural elements Dimensional analysis, materials, fabrication, loading, instrumentation, and interpretation of results are considered. Illustration, by comprehensive laboratory problems, of the use of qualitative and quantitative models to study unusual structural behavior. *Litle*

1.531 ***Special Problems in Structural Engineering*** **(A)**
Prereq.: ——
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. *Holley*

1.541T ***Behavior of Concrete Structures*** **(A)**
Prereq.: 1.51
Year: G (1) 3–0–6
Consideration of the mechanics of reinforced and prestressed concrete structural elements with emphasis on ultimate strength and time-dependent behavior. Systematic procedures for member checking and member design, with emphasis on design criteria. Detailing, formwork design, and construction procedures for *in situ* and precast reinforced and prestressed concrete. *Pahl*

1.542T ***Behavior of Metal Structures*** **(A)**
Prereq.: 1.51
Year: G (2) 3–0–6
Consideration of properties of structural metals including elasto-plastic behavior, buckling, fatigue and brittle fracture phenomena. Problems of fireproofing and fabrication and erection procedures. *Litle*

1.551T ***Planning of Structural Systems*** **(A)**
Prereq.: 1.51
Year: G (1) 3–0–6
Planning of a total structural system to meet given functions. The nature and range of functional requirements for structures. The nature of loadings, the relationship of deterministically vs. statistically based codes. The nature of constraints on structural arrangements brought about by fabrication and erection procedures, and the characteristics and installation procedures for other subsystems involved in the total structure. Emphasis on the conception and initial selection procedure of the structural system by case studies — both those drawn from practice, and problems contrived for student solution, over a range of structural problems including low- and high-rise buildings, long span structures, bridges, and special structures. *Litle*

1.552T ***The Practice of Structural Engineering*** **(A)**
Prereq.: 1.541T, *1.542T*, 1.551T
Year: G (2) 2–3–4
Consideration of the preliminary design including structural concepts, selection of a system to engineer, and the proportioning of members and connections. Several case studies, given with lectures from practicing professionals and faculty members of the division, but presented for solution by students in groups.
R. J. Hansen

1.561 ***Advanced Structural Mechanics*** **(A)**
Prereq.: 1.51
Year: G (1) 3–0–6
Introduction to continuum mechanics: analysis of strain, small and large deformations, compatibility equations; analysis of stress, equilibrium equations; principle of virtual displacements, principle of virtual stresses. Stress-strain-temperature relations for elastic and non-elastic materials. Principles of stationary potential energy and

of stationary complementary potential energy. Plane stress and plane strain. Flexure and torsion of prismatic bars, shear center of thin walled beams, effect of restraint against warping. Technical theory of beams and plates. Small and large deflection theories. Applications of energy principles. *Z. M. Elias*

1.571 ***Advanced Structural Analysis*** **(A)**
Prereq.: 1.51
Year: G (1) 3–0–6

1.572 ***Advanced Structural Analysis*** **(A)**
Prereq.: 1.571
Year: G (2) 2–0–4

Review of matrix algebra. Matrix formulation for an ideal truss including physical and geometrical non-linearities. Discussion of the force and displacement methods of solution. Solution techniques for non-linear trusses. Formulation of the engineering theory for a member element. Application to prismatic, planar, and space members. Matrix analysis of member systems by the displacement and force methods. Development of the finite element displacement method and application to plate and shell structures. Derivation of element matrices for plane stress, plate bending, and combined stretching and bending. *Connor*

1.582 ***Structural Reliability*** **(A)**
Prereq.: 1.07, 1.51
Year: G (2) 2–0–4

Analysis and specification of structural performance and safety through probability. The description of uncertain live, wind, and earthquake loadings. The treatment of material properties' variability. Analysis of the reliability of the performance of structural systems. Optimum design accounting for uncertainty and failure consequences. New and developing code specifications with a probabilistic basis. *Cornell*

1.584 ***Analysis and Design of Shell Structures*** **(A)**
Prereq.: 1.561
Year: G (2) 3–0–6

Formulation of the governing equations of thin shells in orthogonal curvilinear coordinates: analysis of stress; analysis of strain, small and large deformations, compatibility equations. Principle of virtual displacements, principle of virtual stresses. Stress-strain relations for elastic and non-elastic materials. Energy principles. Membrane theory, inextensional bending, conditions for realization of membrane behavior, application to ellipsoids, hyperboloids, paraboloids, cones and cylinders of revolution. Axisymmetric bending of shells of revolution. Shells with edge beams, design considerations, desirability of prestress, variable thickness. Application to various geometries. General theory of cylindrical shells. Design of cylindrical shell roofs. General theory of spherical shells, applications. Shell theory in Cartesian coordinates, shallow shell theory, application to the design of elliptic and hyperbolic paraboloid shell roofs. Applications of energy principles. Elements of stability analysis. *Z. M. Elias*

1.586T ***Structural Dynamics*** **(A)**
Prereq.: 1.51
Year: G (1) 3–0–6

Analysis and design of structures subjected to dynamic loads. Modal analysis of multidegree systems. Numerical methods. Inelastic response. Continuous systems. Practical design methods. Applications to earthquake design, blast-resistant structures, machine supports, bridge vibration, etc. *Roesset*

1.588T ***Structural Stability*** **(A)**
Prereq.: 1.561
Year: G (2) 3–0–6

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. *Roesset*

1.592 ***Structural Information Systems*** **(A)**
Prereq.: 1.00 or 1.151; 1.551T
Year: G (2) 3–0–6

Identification of objectives, decision variables, processes and information flow in structural design. Interrelationships with participating disciplines in building and bridge design. Current building information systems and their technological problems. Current languages and computer systems for structural design, ICES: STRUDLE, BRIDGE, TABLE, and BUILD, information identification, hierarchial data structures. Sensitivity analysis, substructure analysis, man-machine interaction. *Logcher*

1.594T ***Optimization of Structures*** **(A)**
Prereq.: 1.143
Year: G (2) 3–0–6

Mathematical and computer techniques for the optimization of structural designs. Connections with traditional methods of design. Member-level sub-optimization. Linear programming in plastic design. Methods for non-linear design problems: gradient search, cutting plane, geometric programming. Formulation of constraints and objective functions for structural design problems. Integer variables. Choice of design parameters. Approximations and simplifications for formulation and solution of problems. Variation of structural topology and geometry. Optimization under uncertainty. Non-convex design spaces and transformations to convex problems. Use of statistical decision methods for searching local optima. The role of optimization techniques in the structural design process. *Reinschmidt*

1.60 ***Applied Fluid Dynamics***
Prereq.: 1.05
Year: U (2) 3–0–6

Continuation of 1.05. Application of basic principles of fluid dynamics to engineering and environmental problems. Design of pipe line systems including fluid measurement and flow control devices. Compressible flow in conduits, nozzles and diffusers, shock waves in liquids and gases. Resistance of immersed bodies, drag and lift forces and cavitation effects. Turbulent jets and entrainment of fluids. Mixing and diffusion in non-homogeneous fluids. Pumps and turbines in hydraulic engineering systems. Numerical methods in unsteady flows. *Harleman*

1.612 ***Fluid Mechanics***
Prereq.: 1.01, 18.034
Year: G (1) 3–0–6

Introduction to theoretical fluid mechanics. Development of general equations of motion, their significance in dimensionless form, and their application to the solution of problems involving pressure, gravitational, and viscous forces. Emphasis on dynamic similarity, laminar and turbulent flows, surface and form resistance, lift, propulsion, cavitation, and the use of turbomachinery in hydraulic systems. *Eagleson*

1.631 ***Advanced Hydromechanics I*** **(A)**
Prereq.: 1.05 or 1.612; 18.05
Year: G (1) 3–0–6

The kinematics and dynamics of ideal-fluid motions and their mathematical expression. Formulation of boundary conditions. Complex potential and conformal mapping. Virtual mass, airfoil theory, Schwarz-Christoffel transformations and free streamline motions, cavity flows, vortex motions, water waves, and other topics from ideal-fluid theory. *Gelhar*

(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.

1.632 ***Advanced Hydromechanics II*** **(A)**
Prereq.: 1.631
Year: G (2) 3–0–6
Kinematics and dynamics of real-fluid motions and their mathematical formulation. Navier-Stokes equations. Laminar motion and lubrication theory. Stability of laminar motion, origin and generation of turbulence, structure of turbulence and its description. Laminar and turbulent boundary layers. Boundary layers in pressure gradients, separation, stall, secondary flows, boundary layer control. Jets, wakes, and other free turbulent flows. Turbulent mixing, diffusion, and mass transport. Introduction to non-Newtonian fluid mechanics. *Gelhar*

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.: ——
Year: G (1, 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*

1.681 ***Experimental Hydromechanics*** **(A)**
Prereq.: 1.05
Year: G (1) 2–0–4
The role of experimental studies in research and design. Theories of dynamic similarity and dimensional analysis with particular emphasis on their relation to fundamental hydromechanics, interpretation of experimental data and modeling. Criteria for modeling with geometric distortion and other conditions of incomplete dynamic similarity. Fundamentals of measurement and instrumentation. Analysis of the operating principles and performance characteristics of instruments for the measurement of physical quantities such as temperature, pressure and flow. *Perkins*

1.683 ***Experimental Hydromechanics*** **(A)**
Prereq.: 1.631 or 1.681
Year: G (2) 0–6–0
Experimental studies of fundamental flow phenomena such as turbulence, diffusion, boundary layers, fluid vibrations, surface and form resistance, cavitation, wave motion, sediment movement, and density currents. Experimental verification of theory of dynamic similitude and of potential flow analysis. Small group project experiments selected in accordance with particular interests. *Perkins*

1.69 ***Waves and Coastal Processes*** **(A)**
Prereq.: 1.65 or 1.681
Year: G (2) 3–0–6
Hydrodynamics of waves for deep and shallow water, wave generation refraction, energy transmission and dissipation; coastal phenomena, harbor and breakwater problems. Analysis of tides and tidal currents; saltwater-freshwater interaction and diffusion in estuaries; erosion and shoaling in tidal waters. *Ippen, Cross*

1.70 ***Mechanics of Sediment Transport*** **(A)**
Prereq.: 1.65
Year: G (2) 2–0–4
Measurement and description of sediment characteristics. Mechanics of entrainment, movement, and deposition of sedimentary materials by moving fluids. Analysis of roughness and sediment transport rate of alluvial channels. Design of earth canals. Morphology of rivers. *Mei*

1.711 ***Dynamic Hydrology*** **(A)**
Prereq.: 1.05
Year: G (1) 2–0–4
Dynamics of the principal physical processes of interest to the engineering hydrologist. Transport processes in the atmosphere and oceans, energy balance of the earth, atmospheric and oceanic circulations. Emphasis upon the mechanics of evaporation and transpiration, precipitation and snowmelt, infiltration and groundwater flow, the formation of streamflow from rainfall. Structure of the drainage network. *Eagleson*

1.712 ***Hydrologic Analysis and Synthesis*** **(A)**
Prereq.: 1.07, 1.711
Year: G (2) 3–0–6
Analysis and synthesis of hydrologic signals and systems. General structure of hydrologic time series. Identification, analysis and characterization of the deterministic and random components of individual signals. Multivariate methods. Analysis of static and dynamic systems using input-output signals with application to catchment behavior. Linear models of overland flow, infiltration, streamflow and the over-all rainfall-runoff process. Nonlinear models of catchment behavior. Flood and low-flow forecasting. Criteria for instruments and networks. *Eagleson*

1.72 ***Flow in Porous Media*** **(A)**
Prereq.: 1.05, 1.06
Year: G (1) 2–0–4
Hydrodynamics of flow through porous media with emphasis on the physical processes in seepage and ground water hydrology. Continuum approach to porous media. Continuity conditions and equations of motion. Consideration of non-homogeneous and non-isotropic media. Representation of boundary conditions by means of the hodograph method. Analytical methods for steady and unsteady seepage in confined and free surface aquifers. Seepage through embankments and earth dams. Dupuit approximation in phreatic aquifers. Pumping and recharge wells and multiple well systems. Analysis of well tests. Models and analog methods in ground water hydrology. Saline intrusion in coastal aquifers. Hydrodynamic dispersion in porous media, analytical and numerical methods in ground water quality. *Harleman*

1.731T ***Water Resource Systems I*** **(A)**
Prereq. 1.05, 1.143, 1.146
Year: G (2) 3–0–6
Application of systems methodology to the analysis, design, and operation of surface and subsurface reservoirs, networks of pipes and channels, and multipurpose river basin developments. Identification of objectives and system definition. Synthesis of hydrologic inputs, operating rules, optimal design and operation, characteristics of systems performance. *Schaake*

1.732T ***Water Resource Systems II*** **(A)**
Prereq.: 1.05, *1.712, 1.731T*
Year: G (2) 0–3–6
Organization for machine solution of comprehensive problems in hydraulics, hydrology and water resource systems. Analog or digital solution of such problems as flood forecasting, flood routing, transients in closed conduits, reservoir design and operation, water quality forecasting. *Schaake, Perkins*

1.77 ***Water Quality Control*** **(A)**
Prereq.: 1.05
Year: G (2) 2–2–4
Application of fluid mechanics to analysis of problems in water quality and water pollution control. Emphasis

is on the mixing, dilution, and dispersion of pollutants discharged into lakes, rivers, estuaries, or oceans. Development of basic mass transfer equations. Analytical and finite difference computer methods for one-dimensional concentration distributions in rivers and estuaries. Biochemical oxygen demand and dissolved oxygen as water quality indicators. Offshore outfalls and diffusion in the ocean. Analysis of stratified flow systems, selective withdrawal, salinity intrusion in estuaries. Thermal pollution, recirculation and heat dissipation problems associated with fossil fuel and nuclear power plants. Thermal stratification in lakes and reservoirs and its effect on water quality. Optimal design for water quality control. Computation periods and laboratory experiments. *Harleman*

1.96 *Special Studies in Civil Engineering* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Individual (or small group) study of advanced subjects under staff supervision. For graduate students wishing to pursue further study of advanced areas of civil engineering not covered in regular subjects of instruction. *Staff*

1.971 *Research in Civil Engineering* (A)
Prereq.: ——
Year: G (1) *Arr.*

1.972 *Research in Civil Engineering* (A)
Prereq.: ——
Year: G (2) *Arr.*

1.973 *Research in Civil Engineering* (A)
Prereq.: ——
Year: G (S) *Arr.*
For research assistants in civil engineering in cases where assigned research is not used for thesis but is approved for academic credit by the Department. Hours arranged with research supervisor. *Harleman*

1.99 *Special Studies in Civil Engineering*
Prereq.: ——
Year: U (1, 2) *Arr*
Individual study, research, or laboratory investigations under staff supervision for undergraduates. 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. *Staff*

2.
Mechanical Engineering

2.00 *Introduction to Engineering Systems*
Prereq.: 8.02
Year: U (2) 3–3–6
Lectures and demonstrations concerning engineering activities, engineering problems, and representative techniques employed in their solution. Presentation of concepts basic to engineering including systems, models, fields, quantities, and units. Dimensional analysis and similitude with applications to design of engineering systems, planning of tests and experiments, and plotting of engineering data. Introduction to economic selections and proportions. Discussion of engineering materials and their properties. Brief treatment and use of modern computers. Examples and student projects on case studies of historical significance, as well as problems of current interest. *Paynter, I. Paul*

2.01 *Mechanics of Solids*
Prereq.: 8.01, 18.02
Year: U (1, 2) 4–0–8
Extension of Newtonian particle mechanics to continuous bodies of finite size. Introduction to engineering applications of the mechanics of deformable continuous media with focus on the three-dimensional requirements of force equilibrium, geometric compatibility, and material behavior. Definition of the state of stress at a point in a continuum; tensor properties of stress. Definition of the state of strain and of rotation at a point in a continuum and development from the displacement field; tensor properties of strain, strain rate, and rotation rate. Development of idealized constitutive relations for materials exhibiting elastic, plastic, and viscous behavior. Applications to stress distributions and deformations in rods, beams, plates, shafts, and other simple structures of engineering interest. Emphasis on the process of constructing idealized continuous and lumped-parameter analytical models to represent actual physical situations. Concepts of stability of deformable systems. *S. H. Crandall*

2.015 *Mechanics of Solids*
Prereq.: ——
Year: G (S) 2–0–4
Review for naval officers returning for graduate study; a shortened version of 2.01. (*Primarily for students in Course* XIII-A.) *S. H. Crandall*

2.02 *Introduction to System Dynamics*
Prereq.: 8.01, 18.02
Year: U (2) 3–1–8
Dynamic modeling, by linear and non-linear lumped elements, of physical systems involving the storage and transfer of matter and energy. Formulation and solution of governing differential equations by direct analysis and by electronic analog and digital computer methods. Dynamic response and stability of linear systems. Exponential excitation, system functions and pole-zero configurations and their interpretation. Generalized impedance concepts, source equivalents and transformations, and loop and node formulation methods. Unified treatment of active and passive mechanical, fluid, thermal, electrical, and electronic systems and devices. Extensive use of physical examples from the fields of mechanical, electrical, chemical, civil, and aeronautical engineering, business administration, and naval archi- XIII-A.) *Richardson*

2.023 *Dynamic Systems*
Prereq.: ——
Year: G (S) 3–0–6
Review for naval officers returning for graduate study; a shortened version of 2.02. (*Primarily for students in Course* XIII-A.) *Richardson*

2.03 *Dynamics*
Prereq.: 2.02, 18.034
Year: U (1, 2) 3–0–6
Formulation of dynamic equations of motion in mechanical, electrical, and fluid systems by direct and variational methods. Three-dimensional kinematics, inertia tensor, rigid body dynamics. Electrical networks and electromechanical transducers. Treatment of lumped-parameter and continuous systems. Applications to vibrations, wave motions, and frequency response of transducers. *S. H. Crandall*

(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.

2.032 ***Advanced Mechanics*** **(A)**
Prereq.: 2.03 or 2.06
Year: G (1) 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 non-linear vibrations. *Den Hartog*

2.06 ***Vibrations***
Prereq.: 2.03
Year: U (2) 3–0–6
Analysis of vibrations in multidegree-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. *S. H. Crandall*

2.061 ***Random Vibration*** **(A)**
Prereq.: 2.03, 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. *S. H. Crandall*

2.062 ***Wave Propagation*** **(A)**
Prereq.: 2.03, 18.05
Year: G (2) 3–0–9
Wave concepts in applied mechanics with examples chosen from elasticity, acoustics, magnetohydrodynamics, and related subjects. Phase and group velocities, dispersion, energy density and intensity. Transmission, absorption, refraction, diffraction, and scattering of waves. Waves in inhomogeneous media, the WKB and eikonal approximations, ray theory versus full wave theory. The Lamb-Cagniard-Pekeris method. Nonlinear waves, waves in moving or random media. Generation of waves during impact, surface waves, Rayleigh waves, Lamb's problem. Guided waves, normal modes, waves in stratified media. *A. D. Pierce*

2.063 ***Sound and Structural Vibration*** **(A)**
Prereq.: 2.03, 18.05
Year: G (1) 3–0–9
Derivation of acoustic wave equation, small-amplitude approximations. Acoustic intensity and energy density. Generation of sound. The statistical theory of room acoustics. Sound absorption and reverberation time. Direct and reverberant sound fields. Vibration of thin beams and plates. Radiation of sound from vibrating panels, fluid loading effects, critical frequency. Statistical theory of vibrations, response of many-degree-of-freedom systems. Coupling between sound fields and structural vibration; radiation resistance and generalized force. Estimation of average response and variations. (*Alternate years. Not offered 1968–69.*) *Manning*

2.065 ***Flow Noise*** **(A)**
Prereq.: 1.632 or 2.063 or 2.25 or 13.95 or 16.041 or 18.60
Year: G (2) 3–0–9
Lighthill's theory of sound radiated from free turbulence. Kirchhoff's formula for the retarded potential. Source, doublet and quadrupole radiation. Curle's theory of the influence of solid boundaries. Sound from a turbulent boundary layer: wall pressure spectrum, correlation area, Mach number effect, reflection principle for an infinite rigid wall. Radiation from a flexible wall. Theory of vortex sound: edge tone, aeolian tone, feedback effect of resonators. Comparison of theory with experimental results. *Leehey*

2.071 ***Introduction to Solid Mechanics***
Prereq.: 2.01, 2.30
Year: U (1) 3–0–6
Senior or graduate elective providing an introduction to the fundamentals of modern solid mechanics, as applied in areas such as metallurgy, fracture, corrosion, polymer science, design, orthopedic design. Review of stress, equilibrium, displacement, strain, compatibility. Theorem of virtual work. Laws of elasticity; applications of theorems of potential energy, complementary energy, Castigliano, and reciprocity to analysis of elastic structures, composite materials, continuous elastic bodies. Antiplane elastic strain with application to torsion, analysis of shear cracks and elastic aspects of fracture mechanics. Introduction to viscoelasticity. Correspondence principle applied to structures, beams, cracked bodies. Introduction to plasticity, yield conditions, associated flow rule. Limit analysis applied to composite materials, cracked bodies, structures. Antiplane elastic plastic and fully plastic deformation in torsion, cracked bodies. Elements of plane deformation and slip line fields. Elasto-plastic aspects of fracture mechanics. *C. A. Berg*

2.072 ***Solid Mechanics — Introduction to Mechanics of Continuous Media*** **(A)**
Prereq.: ——
Year: G (1) 3–0–9
Geometric foundations of continuum mechanics, conservation laws of mechanics and thermodynamics applied to continuous media. Theorems of virtual work, and converses. Construction of constitutive relations for finite elastic deformation, viscous flow, viscoelasticity, plasticity. Development of basic theorems governing each of these areas of material behavior — e.g., potential and complementary energy theorems of elasticity, correspondence theorem of viscoelasticity, limit theorems of ideal plasticity, conservation theorems of viscous creep — and studies of critical problems in each area — e.g., classical solutions of finite elastic deformation, deformation about dislocations, elastic strain about notches, viscoelastic deformation of structures and cracked bodies, wave propagation in elastic and elasto-plastic rods, dynamic diffusion in linear and non-linear viscous fluids, plastic and elastic properties of composite materials, elasto-plastic deformation about shear cracks with applications to fracture mechanics. Introduction to modern notions of polar media, non-local effects, couple stresses and singularities. *C. A. Berg*

2.073 ***Solid Mechanics — Plasticity and Anelastic Deformation*** **(A)**
Prereq.: 2.071 or 2.072
Year: G (1) 3–0–9
Microscopic and macroscopic aspects of plastic deformation. Yield conditions, maximum plastic work principle and associated flow rule. Studies in fully plastic deformation; limit theorems applied to structures, cracked bodies, composites. Review of elasto-plastic torsion. Plane strain and slipline theory. Antiplane elasto-plastic strain about notches. Examples of numerical solutions to elasto-plastic deformation. High temperature creep and deformation theory plasticity with application to studies of strain fields near notches. The role of strain hardening in stability and uniqueness. Studies of role of plasticity in frictional contact, machining and metals processing, studies of fracture, problems from other areas such as geophysics and biomedical mechanics. *C. A. Berg*

2.083 ***Advanced Mechanics*** **(A)**
Prereq.: 2.071
Year: G (2) 3–0–9
Development of stress equilibrium, strain compatibility and stress-strain-temperature constitutive relations for linear elastic materials. Examples of complete solutions of problems in two and three dimensions and development of approximate solutions for beams, plates, and shells. Consideration of elastic stability. Use of energy methods with emphasis on approximate solutions to complex problems. *Lardner*

2.092 ***Methods of Engineering Analysis*** **(A)**
Prereq.: 18.05
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*

2.101 ***Computer Models of Physical and Engineering Systems I***
Prereq.: ——
Year: U (1, 2) 3–3–6
Elements of automatic computation with emphasis on digital machines and use of the FORTRAN programming language. Concepts concerning the reduction of physical phenomena to simplified physical and mathematical models; their representation by linear graphs and networks. Description and manipulation of the resulting models using digital computers. Examples drawn from fields primarily of interest to engineers. Extensive experience operating programs on the M.E. computer. *(Enrollment limited; preference given to pre-engineering students.)* *Paynter, Rosenberg*

2.13J ***Electromechanical Fields and Systems***
(Same subject as 6.48J)
Prereq.: 2.02 or 6.01
Year: U (1, 2) 4–2–6
Elementary treatment of fields in vacuum and real materials with emphasis on energy principles and force relationships. Emphasis on quasi-static electromagnetic fields through application of Maxwell's equations with brief discussion of gravitational, thermal and fluid fields. Relation between field and lumped-circuit concepts. Multiport energy transformers and transducers. Practical applications to design and utilization of electromechanical devices and systems, including measuring instruments, control components, and rotating machines. Design and laboratory work illustrating practical and theoretical questions. *Paynter, Kingsley*

2.14 ***Control System Principles***
Prereq.: 2.02, 2.201
Year: U (1) 3–1–8
Dynamic analysis and feedback control of lumped-parameter linear systems. Modeling of various electromechanical configurations using scalar and state vector notation. Linearization of non-linear systems. Transient and frequency response to control and disturbance variables. Application of Laplace and Fourier transforms, stability criteria, root locus and other graphical techniques. Practice in design of control systems, using analog and digital computers and actual hardware. *Sheridan*

2.141T ***Modeling and Simulation of Dynamic Systems*** **(A)**
Prereq.: 2.03 or 2.14 or 6.213T or 16.30
Year: G (1) 3–0–9
Modeling of complex linear and non-linear, stationary and time-varying, mechanical, fluid, electrical, and thermal dynamic engineering systems. Emphasis on subdivision into simple multiported elements and representation by the energetic bond graph language. Direct, energetic, and experimental identification. Lumped-field representations. Analytic and graphical reductions and canonical forms, signal graphs, analog, digital and hybrid implementation. Examples including machine components, electromechanical transducers, electric and fluid circuits, and thermal systems. *F. T. Brown*

2.15 ***Control Theory and Application*** **(A)**
Prereq.: 2.14 or 6.213T or 16.30
Year: G (1) 3–0–9
Optimization by calculus of variations. Weierstrass E-Function and Pontryagin Maximum principal. Dynamic programming and optimal control. Application to problems such as flight mechanics, interplanetary trajectories, thermal systems and nuclear propulsion. Extension of optimization theory and application to distributed parameter systems. *Shen*

2.151T ***Advanced System Dynamics and Control*** **(A)**
Prereq.: 18.05
Year: G (1) 3–0–9
Analytical descriptions of dynamic physical systems; concept of state; time and frequency domain representations, experimental methods for system identification. Behavior of unforced dynamic systems and excitation-response patterns; non-linear systems, linearization, response prediction techniques for linear systems. Modification of system characteristics by control techniques; feedback, feedforward, compensation, evaluation of closed-loop performance, physical control devices. Optimization of linear systems, parameter variation and performance evaluation, integral square and mean square criteria. *Karnopp, Richardson*

2.152 ***Modern Control Theory and Applications*** **(A)**
Prereq.: 2.151T
Year: G (2) 3–0–9
Formulation of optimal control problems from engineering situations. Analytical and computational techniques for solving optimization problems; dynamic programming, calculus of variations, maximum principle. Characteristics of optimal systems; bang-bang systems, optimal linear systems. Concepts and analytical treatment of controllability, observability. Control with some inaccessible state variables. Examples of engineering systems involving control of force and motion, thermal effects, and industrial processes. *Karnopp*

2.153 ***Distributed Systems*** **(A)**
Prereq.: 2.062 or 2.14 or 2.141T or 6.07 or 16.30
Year: G (2) 3–0–9
Power and signal flow in distributed media, with emphasis on one-dimensional structuring of engineering systems. Distributed, lumped and mixed modeling and identification of coupled and uncoupled kinetic strain, gravity, thermal, electric and magnetic energies in solids and fluids. Operational, classical, graphical, numerical and analog solution techniques. Frequency and tran-

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sient response, dispersion and attenuation of wave-scattering variables, stability and control. Examples such as beam and plate dynamics, counterflow heat exchangers, fluid and electromagnetic lines, acoustic horns, fluidic systems, electrohydrodynamic and magnetohydrodynamic flow, chemical processes, etc.
F. T. Brown

2.171 *Fluid Power Controls and Fluidics* (A)
Prereq.: 2.14, 2.201
Year: G (1) 3–3–6
Theory and design of hydraulic and pneumatic control systems and components and their applications in aerospace, military, industrial, and other fields. Problems in the control and measurement of pressure, flow, speed, position, force, and other mechanical quantities. Application of basic principles to component and system design. Use of schematic and block diagrams. Solution of typical fluid power control system problems including non-linearities with aid of computers. Current development in the field of fluidics. Design and application of pure fluid amplifiers, logic elements and systems.
S. Y. Lee

2.173 *Instruments for Measurement and Control* (A)
Prereq.: 2.03
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*

2.18 *Man-Machine Systems*
Prereq.: 2.14 or 6.213T or 16.30
Year: U (1) 3–3–6
Man as a component in a physical system. Fundamental concepts pertaining to transmission and processing of information through the human organism. Engineering specification of sensory and muscle transducers. Linear models of the human operator in closed-loop control systems. Bayesian and other probabilistic models of human communication and signal detection. Design of displays and controls for vehicles and man-computer interaction. Laboratory experiments and design practice utilizing a variety of problems in which man interacts with machine. *Sheridan, Ferrell*

2.181J *Life Support and Human Performance in Manned Systems* (A)
(Same subject as 16.43J)
Prereq.: 2.14 or 6.213T or 16.30
Year: G (2) 3–3–6
Environmental control and physiological characteristics of man as related to unusual acceleration, thermal, atmospheric or other stresses. Advanced models of human performance, especially manual control of vehicles. Lectures and student critique of research literature. Design of systems involving man as a decision maker or as a passenger, conducted in small groups throughout the term. *Sheridan, L. R. Young*

2.191J *Special Studies in Systems Engineering* (A)
(Same subject as 1.16J, 6.604J, 13.47J)
Prereq.: ——
Year: G (2) 2–4–6
Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — An integrated urban transportation system; Group 2 — A manned satellite inspection and retrieval system.) *Baumann, de Neufville, Seifert, Frankel*

2.201 *Fluid Mechanics*
Prereq.: 2.01; *2.403* or *2.42;* 18.034
Year: U (1, 2) 4–0–8
Introduction to dynamics of fluid flows, with emphasis on incompressible fluids. Equations of mass conservation, motion, and energy for inviscid and viscous flows, with examples of applications. Bernoulli's integral, Kelvin's theorem on vorticity, potential flow theory, and lift. Navier-Stokes equations, similitude, laminar and turbulent flows in pipes, boundary layer theory. Flow separation and drag. *Sonin*

2.202 *Gas Dynamics*
Prereq.: 2.201
Year: U (2) 3–0–6
Introduction to gas dynamics. Rankine — Hugoniot relations. One-dimensional steady and unsteady flow. Two- and three-dimensional subsonic, supersonic and hypersonic flows. Compressible flow in ducts and channels. Compressible viscous and heat-conducting boundary layers with heat transfer. *Hoult*

2.212 *Fluid Dynamics*
Prereq.: 6.03
Year: U (2) 3–0–6
Selection of fluid dynamics topics from the following areas: compressible gas dynamics, unsteady flows, waves, shocks, magnetohydrodynamics, boundary layer theory, dynamics of highly rarefied gases. (*Not offered 1968–69.*)
Sonin

2.25 *Advanced Fluid Mechanics* (A)
Prereq.: 2.201, *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' vorticity equation and vortex laws. 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. Wave propagation. Applications to fluid machinery, propulsion systems, process industries, and aerodynamics. *A. H. Shapiro*

2.261 *Kinetic Theory of Gases and Plasmas* (A)
Prereq.: 2.273 or 2.46
Year: G (1) 3–0–9
Structure and interactions of atoms and molecules. Calculation of gas properties from statistical mechanical partition function. Collision theory and cross-sections. Derivation of macroscopic transport equations from Boltzmann equation including Lorentz force and radiation. Diffusion, viscosity, thermal, and electrical conductivity of pure gases, mixtures, and plasmas. Radiation transport. Gas-surface interactions and Debye sheath. *Keck*

2.262 *Reaction Kinetics of Gases and Plasmas* (A)
Prereq.: 2.261
Year: G (2) 3–0–9
General theory of gas phase reactions. Analytical and numerical methods for estimating rate constants and cross-sections for rotational and vibrational excitation, dissociation, ionization, and recombination. Line, band, and continuum radiation from atoms, molecules, and ions. Theory of line broadening. Experimental techniques for measuring reaction rates using shock tubes, pipe flows, flash photolysis, atomic and molecular beams, arcs, and discharges. Applications to re-entry, power generation and conversion, combustion, chemical processing, lasers, surface ablation, and atmospheric physics. *Keck*

2.271 *Compressible Fluid Mechanics* (A)
Prereq.: 2.201, 2.403, 18.05
Year: G (2) 3–0–9
Survey of gas dynamics. Fundamentals of wave phenomena. One-dimensional steady flow, with effects of area change, friction, heat transfer, chemical reaction. Shock waves. Supersonic diffusers and wind tunnels. Subsonic high-speed flow. Supersonic flows. Unsteady flows and waves in ducts. Experimental methods. *A. H. Shapiro*

2.272 *Viscous and Turbulent Flows* (A)
Prereq.: 2.25
Year: G (2) 3–0–9
Viscosity and dissipative phenomena; the Navier-Stokes and energy equations, their formulation, properties, and some exact solutions; creeping flows at low Reynolds numbers; laminar boundary layers and their solution; laminar stability, transition, and turbulence; turbulent boundary layers; jets, wakes, and separated flows; thermal boundary layers; compressible boundary layers with chemical reactions, dissociation, and ionization; effects of mass addition and surface catalysis. *Probstein*

2.273 *Molecular Gasdynamics* (A)
Prereq.: 2.201, *18.05*
Year: G (1) 3–0–9
Introduction to fluid flows from the molecular point of view. Molecular models and elementary kinetic theory of gases including pressure, mean free path and transport phenomena. Gas-dynamic regimes. Equilibrium kinetic theory, Maxwellian velocity distribution, collisions and relaxation. Collisionless gas and interaction of a flowing gas with solid surfaces. Approach to thermodynamic equilibrium in fluid flows. Formulation of continuum conservation laws beginning with particle concepts. Transfer and model kinetic equations and their application to low-density flows. *Sonin*

2.274 *Magnetohydrodynamics* (A)
Prereq.: 2.271, 2.273, 6.03
Year: G (1) 3–0–9
Electric and magnetic fields in a moving, conducting fluid. Electrical properties of liquids and plasmas. Kinematics and dynamics of a conducting fluid in an electric and magnetic field. Applications to incompressible two-dimensional flows and laminar boundary layers and one-dimensional compressible flow in a channel. Small and finite amplitude waves in a perfectly conducting gas, MHD shock waves. Effects of finite collision frequency; multicomponent MHD fluid models. (*Not offered 1968–69*). *Fay*

2.275 *Dynamic Fluid Machines* (A)
Prereq.: 2.202 or 2.25
Year: G (2) 3–0–9
Momentum transfer in turbomachines. Axial compressors and turbines: design considerations, cascade aerodynamics including effects of viscosity and compressibility, three-dimensional flow, performance limitations; radial machines; transonic and supersonic compressors; pumps, including effects of cavitation; ducted jets. *Wilson*

2.276 *Advanced Viscous and Turbulent Flows* (A)
Prereq.: 2.272
Year: G (1) 3–0–9
Elements of singular perturbation theory with applications to viscous flows. Hydrodynamic stability and transition to turbulence. Turbulent shear flows including statistical theories and analysis of measurements. Flows with suspended particles and through porous media. Inertial, three-dimensional, and electrohydrodynamic boundary layers. Emphasis on applications to problems in desalination, biomedical fluid mechanics and air and water pollution. *Probstein, Hoult*

2.281 *Reacting Gas Dynamics* (A)
Prereq.: 2.201 or 16.02 or 16.03
Year: G (1) 3–0–9
Fundamental treatment of problems in non-equilibrium gas dynamics involving simultaneous occurrence of chemical reaction and transport of mass, momentum and energy. Applied chemical kinetics. Conservation equations considering chemical reaction and multispecies diffusion. Relaxation phenomena. Method of characteristics for non-equilibrium flows. Acoustic waves, shocks, flames, detonations; their propagation and structure. High-temperature gas flow in jets, nozzles, hypersonic boundary layers. Chemical effects on turbulence. Engineering applications. *Toong*

2.282 *Combustion* (A)
Prereq.: 2.201 or 16.02 or 16.03
Year: G (2) 3–0–9
Comprehensive treatment of combustion principles. Combustion instability, linear and non-linear mechanisms, interactions of acoustic waves with non-uniform and fluctuating reacting flows. Laminar and turbulent flames. Exothermic hypersonic flows. Supersonic combustion. Reacting boundary layers with ablation. Electromagnetic effects. *Toong*

2.283 *Fluid Mechanics of Pollution* (A)
Prereq.: 2.25
Year: G (2) 3–0–9
Application of fluid mechanics to problems of air and water pollution. Properties and sources of air pollutants. Characteristics of atmospheric boundary layer. Turbulent mixing of buoyant plumes and diffusion of pollutants in stratified fluids. Effects of thermal stratification on flow and mixing in air and water. Aerodynamic design of stacks. Aerosol formation, detection, classification and removal. *Fay, Hoult*

2.29 *Advanced Topics in Fluid Mechanics* (A)
Prereq.: 2.25
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.
Fay, Probstein, A. H. Shapiro, Toong

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Descriptions

2.291 *Research in Combustion* (A)
Prereq.: 2.281 or 2.282 or 10.70 or 16.052
Year: G (1 or 2) *Arr.*
Selected theoretical or experimental problems in combustion and high-temperature gas dynamics, including radiative and electromagnetic effects. Work arranged on an individual basis in consultation with instructor.
Toong

2.30 *Mechanical Behavior of Materials*
Prereq.: 2.01, 3.141
Year: U (1, 2) 3–2–4
Mechanics of continua for elastic, plastic, viscoelastic, and creeping materials based on their molecular and dislocation structure and changes in the latter; limit analysis; applications to brittle, ductile, and transitional modes of fracture, to creep, fatigue, friction, and wear. Laboratory emphasizing student-planned projects. McClintock and Argon, *Mechanical Behavior of Materials.*
Argon

2.304 *Physics of Strength and Plasticity* (A)
Prereq.: 2.30, 3.141
Year: G (2) 3–0–9
Molecular mechanisms of rubber-elasticity, viscosity, viscoelasticity and plasticity. Deformation mechanisms in crystalline materials; theories of yield stress, yield phenomena, strain hardening, transient and viscous creep. Types of fracture and theories of fracture; fatigue.
Orowan

2.332 *Dislocation Theory* (A)
Prereq.: 2.01; 2.30 or 3.141
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. Applications to theories of yield points, solution hardening, work hardening, creep and fracture.
Argon

2.34T *Physics and Engineering Use of Adhesives* (A)
Prereq.: ——
Year: G (2) 1–0–3
Peel strength and fracture strength; bond strength and joint strength. Mechanics of joint failure; chemical factors and bond strength. Structural adhesives; simultaneous use of adhesives and fasteners. Adhesives as matrix of composite materials.
Orowan

2.402 *Thermodynamics*
Prereq.: ——
Year: G (1) 4–0–8
Heat, work, the laws of thermodynamics. Entropy and absolute temperature. Properties of liquids, vapors, perfect gases and mixtures of gases and vapors. Applications to heat engine cycles. (*Primarily for selected officers of the U.S. Navy and Coast Guard.*)
J. L. Smith

2.403 *Thermodynamics*
Prereq.: 8.02, 18.034
Year: U (1, 2) 4–0–8
Classical thermodynamics with emphasis on the relation of abstract concepts to physical situations. Work and energy for pure conservative and pure dissipative systems. Heat, temperature, first law of thermodynamics. Pure thermal systems. Equilibrium and reversibility. Thermodynamically coupled systems, second law of thermodynamics, thermodynamic temperature, entropy. Bulk flow and open systems. The pure substance, solid, liquid and gaseous phases. Mixtures of gases. Applications of engineering systems.
J. L. Smith

2.412 *Heat Engineering*
Prereq.: 2.402, 2.54
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.*)
J. L. Smith

2.42 *Elements of Classical and Statistical Thermodynamics*
Prereq.: 8.01, 18.02
Year: U (1, 2) 4–0–8
First and second laws applied to simple systems through the classical concept of state: heat, work, energy, reversibility, entropy, availability, equilibrium, thermodynamic temperature, chemical reactions, chemical potential, chemical equilibrium. The system as an assembly of molecules behaving reversibly. Mechanical state, work of identification of mechanical state, ensemble representation of information, irreversibility and loss of information, entropy of a system represented by an ensemble, application of the criterion of equilibrium to microcanonical and canonical ensembles, a few examples. (*Not offered 1968–69.*)
Keenan

2.451 *Advanced Thermodynamics* (A)
Prereq.: 18.05
Year: G (1) 3–0–9
Equilibrium; first law, second law, state principle, and zeroth law; criteria of equilibrium; temperature, entropy, and availability; Maxwell relations; open systems; phase rule; systems of one and two components; idealized gases, mixtures, and solutions; equations of state; thermodynamic potentials; chemical reactions and chemical equilibrium.
Stickney, Hatsopoulos

2.452 *Advanced Thermodynamics* (A)
Prereq.: 2.451
Year: G (2) 3–0–9
Systems and ensembles; law of stable equilibrium; systems at positive and negative Kelvin temperatures; equilibrium of heterogeneous systems; solutions and electrolytes; gravity and electromagnetic fields; ionized gases; third law. Thermodynamics of fluctuating systems; canonical and grand-canonical ensembles; Fermi-Dirac and Bose-Einstein statistics. Thermodynamics of irreversible processes; Onsager reciprocal relations; diffusion; electronic phenomena in solids, vacua, and plasmas.
Hatsopoulos

2.453 *Advanced Projects in Heat and Thermodynamics* (A)
Prereq.: 2.451
Year: G (1, 2) *Arr.*
Selected subjects of current interest in thermodynamics, mass transfer, and heat transfer. No formal lectures; assigned reading or experiment arranged on an individual basis in consultation with instructor.
Rohsenow, Keck

2.454 *Direct Energy Conversion* (A)
Prereq.: ——
Year: G (1, 2) 3–0–9
Thermodynamic analysis of direct energy conversion processes. Principles of quantum statistics, the Boltzmann transport theory, electronic conduction processes, and thermionic emission. Surface phenomena, theory of sheaths, and electronic transport phenomena through plasmas. The theory of thermionic conversion. Detailed treatment of device characteristics including efficiency, power density, and terminal properties. Introduction to irreversible thermodynamics and its applications to device operations.
Hatsopoulos

2.46 *Statistical Mechanics* (A)
Prereq.: 2.42
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. Application to dissociated gases, plasmas, thermionics, lasers, cryogenics. *Appleton*

2.50 *Heat and Mass Transfer*
Prereq.: 2.201, 2.403
Year: U (1, 2) 3–0–6
Heat, mass, and momentum transfer associated with laminar and turbulent flow of fluids in forced and free convection. Fully developed flows and boundary layer development in ducts, over flat plates and blunt bodies, through tube bundles and packed beds. Heat conduction in solids with and without heat sources; finned surfaces. Condensation. Boiling. Heat exchanger design; heat transfer in nuclear reactors, including liquid metals. Radiative heat transfer. Elementary statistical mechanics. Elementary kinetic theory of gases; distribution function; transport properties. *Rohsenow*

2.53 *Problems in Heat*
Prereq.: 2.403
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*

2.54 *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*

2.55 *Advanced Heat Transfer* (A)
Prereq.: 2.403, *18.05*
Year: G (1) 3–0–9
Review of analogies among heat, mass, and momentum transfer. Free and forced convection from theoretical and experimental viewpoint for laminar and turbulent flows in ducts and over flat plates and blunt bodies. Heat transfer coefficients at high velocities and in rarefied gases. Heat transfer-friction relationship in heat exchangers. Film and dropwise condensation. Boiling with forced and natural convection. Radiative heat transfer; heat transfer between surfaces, in absorbing media. *Rohsenow*

2.56 *Advanced Heat Transfer* (A)
Prereq.: 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*

2.57 *Two-Phase Flow and Boiling Heat Transfer* (A)
Prereq.: 2.201 or 2.25 or 10.52; 2.50 or 2.55 or 10.50
Year: G (2) 3–0–9
Phase change in bulk stagnant systems. Kinematics and dynamics of adiabatic two-phase flow. Dynamics and thermodynamics of forced-convection two-phase flow with boiling and/or evaporation. Thermal and hydrodynamic stability of two-phase flows. Associated topics, such as condensation and atomization. *Bergles, Rohsenow*

2.58 *Radiation Heat Transfer* (A)
Prereq.: 2.42 or 2.403; 2.55; 18.05
Year: G (1) 3–0–9
Basic laws of Thermal Radiation. Radiation properties of solids; electromagnetic theory, dispersion, experimental results. Radiant interchange among surfaces separated by a transparent media; non-gray surfaces, specularly reflecting surfaces. Radiation properties of gases. Radiant interchange through absorbing, emitting and scattering media; radiative equilibrium, combined radiation and conduction; combined radiation and convection; approximate methods of solution. *Cravalho, Glicksman*

2.60 *Applied Thermodynamics*
Prereq.: 2.403 or 2.42
Year: U (2) 3–0–6
Case study of a situation applying the approaches and techniques developed in 2.42. Choice of cases providing introduction to heat and mass transfer and to the kinetic theory of rate processes. Study of simple concepts in boundary-layer fluid mechanics and in diffusion and viscosity. *D. G. Wilson*

2.611 *Elementary Internal Combustion Engines*
Prereq.: 2.02, 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*

2.612 *Internal Combustion Engines*
Prereq.: 2.611
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*

2.614 *Internal Combustion Engine Laboratory*
Prereq.: 2.611
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*

2.615 *Advanced Internal Combustion Engines* (A)
Prereq.: 2.02, 2.403
Year: G (1) 3–0–9
Similar to 2.611, but for students with some previous training or experience in this field. Analytical approach to the engineering problems and performance estimation, of diesel, spark ignition and mixed cycle engines. Study of fluid flow, thermodynamics, combustion and other factors affecting power and efficiency. *Rogowski*

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2.616 ***Advanced Internal Combustion Engines*** **(A)**
Prereq.: 2.611 or 2.615
Year: G (2) 3–0–9
Continuation of engine theory. Philosophy of design and design procedure. Synthesis of the optimum design to satisfy given performance specifications. Similar to 2.612 but includes an individual engine design project, with application and specifications selected by the student. *Rogowski*

2.617 ***Special Problems in Internal Combustion Engines*** **(A)**
Prereq.: 2.611; 2.615 or 2.621
Year: G (1 or 2) *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*

2.618 ***Automotive Vehicles***
Prereq.: 2.03
Year: U (2) 3–0–6
Analytical approach to vehicle performance, handling, and riding qualities. Design of body, chassis, suspension, engine, and transmission to meet vehicle requirements. Individual study of a special problem related to automobile design. Demonstrations of vehicles and components. *Larrabee*

2.621 ***Gas Turbines*** **(A)**
Prereq.: 2.202; 2.403 or 2.42; 2.60
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 and consideration of special problems encountered in aircraft. *D. G. Wilson*

2.632 ***Research in Lubrication*** **(A)**
Prereq.: ——
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*

2.641 ***Food Engineering***
Prereq.: 8.01
Year: U (1) 3–2–3
Primarily for students in Nutrition and Food Science. Fundamental principles of thermodynamics including laboratory work. Development of basic refrigeration cycles and their application. *Hesselschwerdt*

2.642J ***Food Engineering***
(Same subject as 20.13J)
Prereq.: 2.641
Year: U (2) 4–0–5
Quantitative study of selected unit operations of the food industry with consideration of basic principles governing each operation, as well as of important applications. Emphasis on refrigeration and freezing, fluid flow, heat transfer, evaporation, dehydration and filtration. *Hesselschwerdt, Karel*

2.643 ***Air Conditioning***
Prereq.: 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*

2.644 ***Environmental Control — Air Conditioning***
Prereq.: 8.02
Year: U (2) 3–0–5
Primarily for students in Architecture. Physiological and functional aspects involved in producing and controlling a thermal environment. Relationship of space and enclosure to climate and weather. Development and analysis for heating, cooling, ventilation, and air distribution. Principles and techniques of cooling. Evaluation of allocation of space for equipment and systems in the building source and conveyance media. Lecture material supplemented with plant and site trips. *Hesselschwerdt*

2.645 ***Advanced Air Conditioning*** **(A)**
Prereq.: 2.643
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. Consideration of typical air conditioning equipment and control systems in relation to specific problems. *Hesselschwerdt*

2.646 ***Refrigeration***
Prereq.: 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. *Hesselschwerdt*

2.647 ***Vehicle Environmental Control***
Prereq.: 2.201 or 2.50 or 16.02; 2.403
Year: G (1, 2) 3–0–6
Environmental requirements for equipment and for human habitation. Psychological and physiological principles of the interrelation between a human and his surroundings. Consideration of the limitations imposed upon the environment by the mission, such as in a space vehicle, supersonic aircraft or submarine. Thermodynamics of heat and mass transfer in air mixtures as related to the control of temperature, humidity, and purity. Study of the basic characteristics of various types of equipment, such as heat exchangers, compressors and expansion engines, and control devices. System integration and optimization. Extensive study of a particular system with emphasis on the application of fundamental principles to the design of a practical environmental control system. *Hesselschwerdt*

2.649 ***Low Temperature Refrigeration*** **(A)**
Prereq.: 2.403 or 2.42
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. Laboratory projects on related topics according to individual interests. *J. L. Smith*

2.652 ***Experimental Stress Analysis***
Prereq.: 2.01
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, as applied to problems involving static, dynamic, and residual stress distributions. *Murray*

2.653 ***Research in Experimental Stress Analysis* (A)**
Prereq.: 2.652
Year: G (1 or 2) *Arr.*
Application of experimental methods to the solution of special problems; current development of theory and technique. *Murray*

2.654 ***Physical Measurement and Analysis***
Prereq.: 8.02, 18.02
Year: U (1, 2) 2–6–4
Experimental techniques presented for observation and measurement of fundamental engineering quantities such as: displacement, force, torque, time, velocity, acceleration, temperature, pressure, and flow. Quantities for carrying out these measurements including the following: electrical (resistive, inductive, capacitive), mechanical, pneumatic, hydraulic, radio-tracer, and optical. Emphasis on a physical (and analytical) understanding of the static and dynamic behavior of measurement systems. Discussion includes statistical and dynamic analysis of data as well as dynamic analysis of the physical systems. Development in lectures of the background required for conducting the laboratory projects. Grading based primarily on laboratory reports.
Cook, Rabinowicz, Syniuta

2.67 ***Design and Experiment***
Prereq.: 8.02, 18.02
Year: U (1) 2–6–4
Student-defined research tasks relevant to an over-all goal of current interest. Definition of tasks, formulation of analytical models, and design and execution of apparatus, research plans, and experiments by small student groups under individual faculty counsel. Results periodically related to goal through student presentation and critique. *D. G. Wilson*

2.672 ***Experimental Engineering I***
Prereq.: 2.01, 2.02, *2.201*; *2.403* or *2.42*
Year: U (2) 1–3–2
Engineering laboratory subject for mechanical engineering juniors. Major emphasis on the interplay between analytical and experimental methods in the solution of research and development problem. Groups of three students to work together on three problems for the term. Introduction to Mechanical Engineering Laboratory. *Griffith*

2.673 ***Experimental Engineering II***
Prereq.: 2.672
Year: U (1) 0–4–2
Engineering laboratory subject for mechanical engineering juniors. Continuation of 2.672, consisting of a single project to be worked on by a group of students under the supervision of a staff member. A report and presentation required at the end of the term. *Griffith*

2.701J ***Architectural Communication***
(Same subject as 4.701J)
Prereq.: ——
Year: U (1, 2) 4–2–2
Communication with self (visualization), with others (presentation), and with machines (manipulation). Introduction to orthography, perspective, projective geometry, matrix algebra, descriptive geometry, diagrams, and models. Relationship between communication media and process or product. *Coons, Negroponte*

2.711 ***Engineering Geometry***
Prereq.: ——
Year: U (1, 2) 0–4–2
Graphical techniques of definition, analysis, and design applied to engineering problems. Use of descriptive geometry to display and examine schemes and devices, to comprehend and solve problems, and to explore and create new things. Mastery of projection, precision drawing, and technical sketching through application. Assignments of typical engineering problems to challenge ingenuity and provide experience in design. Study of kinematic design and analysis of mechanisms. New projects each term involving the design of such items as space frames for structures, mechanisms for three-dimensional motion, developable surfaces for boats, portable buildings for special purposes. *Lent*

2.723 ***Elementary Nomography***
Prereq.: ——
Year: U (1, 2) 2–0–4
Graphical representation and solution of equations by alignment diagrams based upon plane geometry and determinants. Extensive graphical use of central projection, duality of point and line, axis of homology, cross-ratio, and other projective tools. Treatment of empirical data. Countable bit representation of functional behavior. Elementary programming and computer-plotting of charts. *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. Introduction to projective methods. Classical and modern necessary and sufficient conditions for nomographic form. Quasi-alignment diagrams, near-canonical forms, extensive treatment of alignment diagrams for empirical data. Countable bit representation of nomographic functional behavior. Elementary programming and computer plotting of nomographic charts. Nomographic solutions of systems of ordinary differential equations using Runge-Kutta methods.
D. P. Adams

2.726 ***Computer-Aided Design* (A)**
Prereq.: 18.05
Year: G (2) 3–0–9
Study of newly emergent techniques for manipulation of large-scale digital computers in connection with the design process. Graphical input and output programs with their influence on techniques of shape description. Mathematics and graphics of general curved surfaces, curve fitting, curve smoothing. Graphical and symbolic methods for communication of the logical structure of problem solutions. *Coons*

2.731 ***Engineering Design***
Prereq.: 2.02, 2.861
Year: U (1) 3–3–6
Instruction and experience in the integrated aspects of creative design and design analysis. In the context of an over-all system theme, individual students define and design interrelated projects, with original concepts and thorough engineering analysis equally stressed; lectures devoted to background information, competitive approaches, and pertinent disciplinary and theoretical material; frequent student presentations and critiques culminate in formal "professional" presentation to experts from industry and government. *Paul*

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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 Problems in Systems and Design*
Prereq.: 2.731
Year: U (1, 2) *Arr.*
For undergraduates desiring to carry on substantial projects of own choosing in the areas of engineering design, system analysis or automatic control. Special lectures and seminars to be arranged when appropriate. Projects arranged on individual basis in consultation with instructor. *Richardson*

2.734 *Advanced Projects in Systems and Design* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For graduate students desiring to carry on substantial projects of own choosing in the areas of engineering design, system analysis or automatic control. Special lectures and seminars to be arranged when appropriate. Projects arranged on an individual basis in consultation with instructor. *Richardson*

2.736 *Modern Kinematic Problems*
Prereq.: 2.01, 18.034
Year: U (1, 2) *Arr.*
The extraordinary basic properties of plane rigid motion: centers of velocity and acceleration, centrodes, the inflection and return circles, the cubic of constant curvature, Ball's point, the Laws of Euler-Savary and Bobillier, etc., with applications. Burmester four-bar linkage theory for five desired positions of the plane. Nomographic, graphic, and analytic synthesis of generator linkages and couplerpoint curves. Modern space-linkage synthesis using dual numbers and quaternions with corresponding matrix treatment. Computer programming for optimizing modern kinematic solutions and plotting them. *D. P. Adams*

2.86 *Manufacturing Project Laboratory*
Prereq.: ——
Year: U (1, 2) 2–3–1
Discussion and laboratory experience covering modern methods of manufacture. First laboratory sessions directed towards development of the capabilities and limitations of manufacturing methods. Later laboratory sessions involving experimental investigation in depth of particular manufacturing operations with emphasis on the effects of material properties, friction and wear, and cost. Grading on the basis of laboratory work and reports. *P. A. Smith, Cook*

2.861 *Engineering Design and Manufacture*
Prereq.: ——
Year: U (2) 4–4–4
Design principles applied to machine components. Philosophy of design stressing the creative approach to engineering problems. Comprehensive design project integrating functional requirements, proportions of elements and methods of production. Description and mechanics of manufacturing processes. Determination and application of material test data to process analysis. Application of economic principles to manufacturing. *Lent, Cook*

2.862 *Machine Tool Fundamentals*
Prereq.: 2.86 or 2.861
Year: U (1, 2) 2–1–2
Analysis of manufacturing processes with emphasis on manufacturing economics. Tool life studies, optimization of material removal rates, process and equipment selection based upon capabilities and minimum cost. Principles of quality control. Discussion of industrial organization and personnel problems associated with manufacturing. *P. A. Smith*

2.865 *Theory of Material Interface Phenomena* (A)
Prereq.: ——
Year: G (1) 3–0–9
Theory of surfaces and interfaces, and influence of surface geometry and surface chemistry. Transmission of force, heat, electricity, mass. Phenomena of friction, wear, lubrication and adhesion. Characteristics of materials particularly suitable for interface action. Experimental investigation of interface phenomena.
Rabinowicz, Rightmire

2.866 *Application of Material Interface Phenomena* (A)
Prereq.: ——
Year: G (2) 3–0–9
Theories of metal processing including new electrical methods. Sliding systems including hydrodynamics, hydrostatics, gases, rolling contacts, and gears. Instrumentation applicable to this field. Statistical analysis of interface phenomena, and deduction of events occurring at the interface. *Cook, Nayak*

2.869 *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*

2.901J *Polymer Materials Science*
(Same subject as 10.641J)
Prereq.: 5.01
Year: U (1) 3–0–9
Principles of macromolecular structure, their relation to properties of polymers and application to the design of engineering materials. Statistics of macromolecules and experimental determination of their sizes and shapes. Model structures: helices, extended chains, folded-chains and random coils. Theories of rubber elasticity, glass transitions and crystalline melting transitions. Melt rheology and extrusion theory. Survey of engineering properties of rubbers, proteins, glasses, plastics, and fibers. *Yannas, A. S. Hoffman*

2.903 *Elements of Textile Materials and Processes*
Prereq.: ——
Year: U (1) 3–0–6
Characteristics of fibers as affecting processing and performance of textile intermediate and end products. Principles of textile manufacturing: treating operations such as blending, carding, combing, drafting, twisting, etc., and their combination into processes for natural and man-made fibrous materials. Principles of structural design of twisted, woven, knitted, braided, and felted materials. *Backer*

2.904 ***Fiber Processing Dynamics***
Prereq.: 2.03
Year: U (2) 3–0–6
The mechanical interaction between fiber process manufacturing operations and the fiber, yarn, or fabric in process. Dynamics of fiber process operations, including analysis of ring spinning mechanics, balloon dynamics, traveller ring interactions, spindle vibration, shuttle dynamics, tension control, and fabric guiding and winding control. Process theory relating to product irregularity, blending statistics, drafting mechanics, and breakage probabilities. *Backer*

2.905 ***Mechanics and Optics of Polymers*** **(A)**
Prereq.: 2.30; or 2.901J; or 5.01, 8.02
Year: G (1) 3–0–6
Theory of linear viscoelasticity and applications to the relaxation, creep, dynamic and stress-strain behavior of amorphous polymers. Principles of time, temperature and concentration superposition applicable to the small strain behavior of amorphous polymers. Principles of interaction of electromagnetic radiation with matter and their application to structural problems in amorphous and paracrystalline polymers. Specification of chain and crystallite orientation by X-ray diffraction, infrared dichroism and birefringence. Combined mechanical, thermal and optical studies of yielding, cold drawing and fracture phenomena in polymers, polymeric composite materials and biomaterials. *Yannas*

2.906 ***Principles of Macromolecular Physics*** **(A)**
Prereq.: 2.30; or 2.901J; or 5.01, 8.02
Year: G (2) 3–0–6
Elements of probability theory and their systematic application to the distribution of molecular weights, conformations and shapes of macromolecules; emphasis on the systematic construction of conceptual chains. Statistical mechanical theories of ensembles of macromolecules with specific reference to rubber elasticity, crystalline melting and glass transitions of polymers. Experimental testing of structural models and of statistical theories for synthetic as well as for biological macromolecules. *Yannas*

2.911T ***Polymer Physics Laboratory*** **(A)**
Prereq.: ——
Year: G (1 or 2) 3–6–3
Determination of viscoelastic and physicochemical constants of synthetic polymers and biopolymers. Application to current research problems in the relation of molecular structure to the macroscopic properties of fibers, plastics, glasses, rubbers and proteins. Design of novel instruments for polymer research. (*Limited enrollment. Open to advanced undergraduates by permission of instructor.*) *Yannas*

2.912 ***Fiber Research Laboratory*** **(A)**
Prereq.: 2.913
Year: G (2) 3–3–2
Application of the research group method to solution of experimental problems. Exercise in analysis of material and structural properties affecting intermediate or end product behavior and in design of apparatus and/or experiments in fiber mechanics. *Backer, Valko*

2.913 ***Fibers and Polymers Seminar*** **(A)**
Prereq.: 2.30
Year: G (1) 2–0–2
Discussions of current problems in applied mechanics of fibrous assemblies. Differential geometry of twisted structures; translation of fiber properties into yarn behavior; role of fiber variability; mechanics of paper and other fibrous sheet materials; interaction of yarn and fabric structures. Analysis of woven, knitted, laminate, and composite materials used in engineering and apparel applications. *Backer*

2.914 ***Fibers and Polymers Seminar*** **(A)**
Prereq.: 2.913
Year: G (2) 2–0–2
Student and staff participation in critical discussions of important problems in fiber and polymer rheology, applied mechanics of fiber structures, and dynamic interactions between fibrous structures and manufacturing processes, together with reviews of the current literature and the results of researches in these fields at the Institute. *Backer*

2.951 ***Industrial Practice***
Prereq.: ——
Year: U (S) 40 h.p.w.

2.952 ***Industrial Practice***
Prereq.: ——
Year: U (1, 2) 0–8–0
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*

2.96J ***Legal Aspects of New Technology***
(Same subject as 16.79J)
Prereq.: ——
Year: G (1) 3–0–6
Intellectual property and the law. The nature and progress of invention past and present, the evolution of relevant legal doctrines as an expression of public policy, and present legal doctrines for the treatment of intellectual property as trade secrets, proprietary data, copyrighted materials and patents. Critical analysis of the patent and copyright systems and pending legislation. The impact of selected new technologies — computer technology and xerography. The role of the Federal agencies — with emphasis on the Department of Defense and NASA. The employer-employee relationship, incentives for innovation, employment restraints and employee mobility. Term paper or project required. *Baram*

3.
Metallurgy and Materials Science

3.00 ***Thermodynamics of Materials***
Prereq.: 5.01, *8.02*
Year: U (1) 4–0–8
Essential concepts of thermodynamics and their application to the behavior of metals and materials. The first law of thermodynamics; thermochemistry; enthalpies of reaction, transformation, and solution. Introduction to the second law, entropy, the third law, work functions, chemical potential, and the phase rule. An introductory treatment of statistical thermodynamics. *de Bruyn, 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.

Descriptions

3.01T ***Thermodynamics and Statistical Mechanics***
Prereq.: 3.00, 18.034
Year: U (1) 3–0–9
Intermediate thermodynamics and elementary statistical approaches. State properties and Jacobians; the first and second laws, heterogeneous and homogeneous equilibrium. Solutions. Electrochemistry. Surfaces and fields. Phase space; ergodicity; Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics. Equipartition; specific heats of classical and degenerate systems. Boltzmann transport equation; irreversible thermodynamics.
R. M. Rose, Russell

3.02 ***Chemistry of Materials***
Prereq.: 3.00, 5.01
Year: U (2) 3–3–6
Chemical characteristics of useful materials, elemental and compound. Relation of chemical properties to atomic structure and bonding. Quantitative measures of reactivity. Preparation of pure materials. Reaction of materials with environment, including protection.
T. B. King

3.03 ***Chemical Metallurgy***
Prereq.: 3.01, 3.02
Year: U (1) 3–0–6
Application of principles of 3.02 to treatment of important metallurgical processes according to stoichiometric, thermodynamic, and kinetic viewpoints. Gas-solid reactions such as reduction of oxides. Slag-metal reactions in smelting. Gas-liquid processes such as distillation. Refining processes such as precipitation, segregation, vacuum melting and degassing. *T. B. King*

3.04 ***Materials Research Laboratory***
Prereq.: 5.01, 8.01
Year: U (1, 2) 1–3–2

3.05 ***Materials Research Laboratory***
Prereq.: 5.01, 8.01
Year: U (1, 2) 2–6–4
Laboratory work on structure-property relations in materials. Introduction for all students to structure analysis techniques such as metallography (examination by light microscope) and X-ray crystallography, followed by assignment of each student to an individual faculty member and research project in one area, such as: mechanical properties, crystal growth, surface chemistry, electronic materials, superconductivity, electron microscopy, ceramics, chemical processing, electron diffraction, magnetic properties, high-temperature alloys, crystal imperfections. Periodic classroom discussion of laboratory project. *Gatos*

3.06 ***Ceramics***
Prereq.: 3.00, 5.01, 18.034
Year: U (2) 3–0–6
Introduction to ceramics as a class of materials, emphasizing both advantages and disadvantages for selected uses. Application of structural knowledge, thermodynamics, and theories of deformation and transport processes to the analysis and understanding of selected ceramic processes, including fabrication of glasses and glass-ceramic materials, slip casting, plastic forming and sintering. *Mogab, Uhlmann*

3.07 ***Physical Ceramics I***
Prereq.: 3.13 or 3.141
Year: U (1) 3–0–6
Characteristics of vitreous and crystalline non-metals. 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, Wuensch*

3.08T ***Principles of Materials Separation***
Prereq.: 3.00
Year: U (2) 3–0–6
Separation of materials in solid, liquid, or gaseous form according to bulk or surface properties. Consideration of physical separations according to size, density, surface characteristics, magnetic and electrical properties. Chemical separations including adsorption, dissolution, precipitation, solvent extraction, and electrolysis. Application of principles to representative processes.
de Bruyn

3.09 ***Structure and Properties of Solids***
Prereq.: ——
Year: U (1) 3–0–3
Lectures and demonstrations on selected topics of atomic, molecular and crystal structure of solids. Correlation of physical and chemical properties of solids with composition, structure, and environmental factors. *Wulff*

3.10T ***Structure and Properties of Electronic Materials***
Prereq.: ——
Year: U (2) 3–0–6
Lectures and experimental demonstrations concerning the influence of atomic, crystal, and phase structure on the electronic processes in solids. Discussion of the influence of composition, processing and environment on the properties of useful electronic materials. *R. M. Rose*

3.11 ***Mechanics of Materials***
Prereq.: 8.01, 18.02
Year: U (2) 4–0–8
Response of materials and devices to applied forces interpreted on different structural bases, from the idealized continuum to the imperfections in natural crystals and molecular arrays. The transition from particle to continuum mechanics. Problems in statics. Structure of crystals. Elasticity: states of stress and strain; problems in rod- and sheet-like sections. Plasticity: behavior of crystals; combined-stress yielding in isotropic and anisotropic materials; strain hardening. Fluidity and viscosity. Fracture: theory and control in real materials.
Backofen

3.12 ***Principles of Crystallography and X-ray Diffraction***
Prereq.: 8.02, 18.02
Year: U (1) 4–3–5
Introduction to the nature of the solid state. Crystal geometry; space lattices, crystal systems, symmetry classes, and space groups. Atomic arrangements in crystals and their determination by X-ray diffraction. Application of the reciprocal lattice in the solution of X-ray diffraction problems. The use of X-ray diffraction in the study of crystals by the Laue, rotating crystal, and powder methods. The role of atomic arrangements in polymorphism, order-disorder, phase transformations, deformation, and crystal growth. *Ogilvie, Wuensch*

3.13 ***Materials Science I***
Prereq.: 3.01, 3.11, 3.12
Year: U (2) 4–3–5
Principles underlying the physical, mechanical and chemical properties of metals, ceramics, and polymers. Equilibrium and non-equilibrium phase relationships in one-, two-, and three-component systems; relation of symmetry to physical properties of crystals; mechanisms and kinetics of diffusion; structural imperfections and their influence upon mechanical properties; oxidation and corrosion. Emphasis upon correlation of properties with crystal structure and microstructure, including quantitative metallography. Use of laboratory experiments on some of the basic techniques to evaluate the structure and properties of materials. *Cohen, Breedis*

3.14 *Physical Metallurgy I*
Prereq.: 3.13 or 3.141
Year: U(1) 4–3–5
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. *Bever, Cohen*

3.141 *Science of Materials*
Prereq.: 8.01
Year: U (1, 2) 4–3–5
Principles underlying the structure and properties of materials. Lecture and laboratory work in atomic, molecular, crystal, and phase structure of solids. Emphasis on equilibrium and non-equilibrium transformations in multicomponent systems. Study of the kinetics of nucleation and diffusion in relation to recovery, recrystallization, and grain growth. Correlation of structure in metals, ceramics, and polymers with chemical and mechanical behavior. Laboratory experiments concerned with structure and properties of materials.
Flemings, R. M. Rose

3.144 *Physical Metallurgy I*
Prereq.: 3.13 or 3.141
Year: U (1) 4–0–4
Same as 3.14 but without laboratory.
Bever, Cohen

3.15 *Materials Science II*
Prereq.: 3.13, 8.03T, 18.034
Year: U (2) 4–3–5
Introduction to the physics of solid materials from a phenomenological or experimental point of view. A brief discussion of the quantum theory of atomic structure, followed by a treatment of solids invoking free electron and nearly free electron concepts. Topics discussed: electrical and thermal properties of metals, semiconductors and insulators; optical properties; magnetic properties, including the simpler theories of dia-, para- and ferromagnetism. Treatment centered on the effect of structure, both atomic and microscopic, on physical properties. Selected experiments performed in the laboratory; a time-sharing computer used for problem solving, employing the MAP system, and requiring no prior computing experience. *Kaplow, Moss*

3.16 *Physical Metallurgy II*
Prereq.: 3.14 or 3.144
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. *Grant*

3.17 *Case Histories in Engineering Science*
Prereq.: ——
Year: U (2) 3–0–3
Study of actual processes leading to induction of generalizations and their subsequent application in science and engineering. Discussion in depth of a few case histories of recent and current investigations in which M.I.T. metallurgy and materials science faculty have played an active role. Participation by the students in evaluating key factors leading to scientific and engineering success on the basis of these detailed case histories. *Kingery*

3.18 *Materials Processing*
Prereq.: 3.13 or 3.141
Year: U (1) 4–3–5
Fundamentals of heat flow applied to hardening metals, tempering glass, foundry mold design, and splat cooling. Heat and material flow applied to solidification of metals and alloys, forming glass, zone refining and welding. Emphasis on control of structure and texture. Material flow applied to glass drawing, metal rolling, extrusion of materials, vapor growth of crystals, powder processing of metals and ceramics, hot pressing, and metal-ceramic sealing. Choice of experiments from current laboratory processing studies and operations.
Coble

3.188 *Materials Processing*
Prereq.: 3.13 or 3.141
Year: U (1) 4–0–4
Same as 3.18 but without laboratory. *Coble*

3.20 *Thermodynamics in Metallurgy* (A)
Prereq.: 3.01
Year: G (1) 4–0–8
Advanced treatment of the thermodynamic properties of inorganic materials. Introductory statistical thermodynamics and surface thermodynamics. Application of the laws of thermodynamics to the chemical behavior of elements, compounds and solutions. Discussion of heterogeneous equilibria, chemical reactions, effect of different potential fields and the thermodynamics of structural defects. *Elliott*

3.21 *Kinetics in Metallurgy and Materials Science* (A)
Prereq.: 3.01, 3.13
Year: G (1) 4–0–8
Unified treatment of kinetics from phenomenological and atomistic viewpoints. Diffusion in metals and nonmetals, including boundary value problems in growth, coarsening, and homogenization; mechanisms, high diffusivity paths, and diffusional instabilities. Rate laws, consecutive and competing reactions, absolute rate theory. Homogeneous and heterogeneous nucleation kinetics including condensation, film deposition, solidification, precipitation and diffusionless transformations. Frequent introduction of examples to illustrate principles discussed. *Cahn, Elliott*

3.22 *Defects in Solids* (A)
Prereq.: 3.01, 3.13
Year: G (2) 4–0–8
Point, line, and surface defects considered primarily from a theoretical viewpoint. Tensor elasticity treated as prelude to dislocation theory. Theory of perfect and dissociated dislocations and their interactions with surroundings. Surface thermodynamics with regard to equilibrium forms, kinetics, and stability. Equilibrium configuration, formation, and removal of point defects in metallic and non-metallic materials. *Russell*

3.23 *The Structure of Matter* (A)
Prereq.: 3.12
Year: G (2) 3–0–9
Atomic arrangements and symmetry elements which describe crystalline and non-crystalline liquids and solids; physical and chemical properties for a number of significant cases to emphasize the important features of these structures. Brief treatment of methods used in determining structures as they apply to each class of materials; principal objective, to provide a systematic treatment of atomic configurations in order to introduce a structural basis for the discussion of electrical, magnetic, and other physical properties. *Averbach*

(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.

3.24 ***Structure and Properties of Metals*** **(A)**
Prereq.: 3.12; 3.14 or 3.144
Year: G (2) 3–0–6
Systematic treatment of the relations between the structure of metals and their properties. The elements of structure, especially grain structure; substructure, preferred orientation and the morphology of multiphase systems, with emphasis on quantitative aspects. The structural features of order phenomena, coherency and cold worked metals. Analysis of the effects of structural variables on mechanical, electrical, magnetic and other selected properties. *Bever*

3.30 ***Strengthening Mechanisms in Metals*** **(A)**
Prereq.: 2.332 or 3.22
Year: G (1) 2–0–4
Theories of strength of perfect and imperfect crystals, solid-solution hardening, strain hardening, crystal-size effects and precipitation hardening. Emphasis upon both the fundamental and applied aspects of achieving high strengths in metals through control of composition and structure. Frequent reference to current literature. *Breedis*

3.31 ***Phase Transformations in Metals*** **(A)**
Prereq.: 3.20, 3.21
Year: G (2) 3–0–9
Advanced treatment of phase transformations, including solidification, crystal growth, precipitation, eutectoids, recrystallization and grain growth, order-disorder and martensite. Emphasis on phenomenological understanding of kinetics and resultant morphology in terms of thermodynamics, transport processes and interface structure. *Cahn*

3.32 ***Electron Microscopy of Crystalline Materials*** **(A)**
Prereq.: 3.12
Year: G (2) 2–0–4
Introduction to the optics of the electron microscope, electron diffraction, moiré effects, and diffraction contrast mechanisms in foils containing lattice defects and second phases. Consideration of the quantitative evaluation of structure, and methods of specimen preparation including thin foils and replicas. Emphasis on the interpretation of images and diffraction effects, and the reliability of the method in various applications. (*Not offered 1968-69.*) *Breedis*

3.33 ***Electron Optics***
Prereq.: 3.13 or 3.141
Year: G (2) 1–3–2
Electron optical systems employed as basic research tools presented from the viewpoint of design, construction and application. Laboratory dealing with problems encountered in metallurgical studies. *Ogilvie*

3.34 ***Advanced X-ray Metallurgy*** **(A)**
Prereq.: 3.12
Year: G (2) 1–3–2
More detailed treatment of principles discussed in 3.12T. Short research projects that deal with the study of particle size, strain, phase diagrams, diffusion, hardening and related topics carried out in the laboratory. *Ogilvie*

3.35 ***Solidification Processing*** **(A)**
Prereq.: 3.13 or 3.141
Year: G (2) 2–0–4
Principles of control of structure, properties, and shape in processes involving liquid-solid and vapor-solid transformations. Heat flow, solute redistribution, nucleation, growth kinetics. Resultant structures and properties. Examples drawn from commercial processes, including metal casting, zone refining, electrodeposition, and crystal growth from the melt, vapor, and solution. *Flemings*

3.36 ***Welding Engineering*** **(A)**
Prereq.: 3.13 or 3.141
Year: G (2) 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. (*Not offered 1968-69.*) *C. M. Adams*

3.37 ***Deformation Processing*** **(A)**
Prereq.: 3.11; 3.13 or 3.141
Year: G (1) 2–0–4
Processing for shape change and property control by plastic deformation and fracture. Analyses of processing systems in terms of basic, interacting problem areas. Strength and plasticity in isotropic and anisotropic or textured states; slip-line field and limit analysis. Boundary conditions of friction and lubrication in a two-metal interface. Material behavior at high temperature and strain rate; structural changes, plastic instability and fracture; viscous forming. Resulting microstructure, texture, and properties. Apparatus and control as related to process choice and trends in processing. Examples for discussion from a wide range of industrial operations. *Backofen, Holt*

3.38 ***Behavior of Metals at Elevated Temperatures*** **(A)**
Prereq.: 3.13 or 3.141
Year: G (1) 2–0–4
Study of metal and alloy behavior above the minimum recrystallization temperature. Creep, stress rupture and fatigue interpretation. Relationships between structure and properties in terms of strength and ductility. Strengthening mechanisms. Nature of high temperature deformation and fracture. *Grant*

3.40J ***Laboratory in Physics of Solids*** **(A)**
(Same subject as 6.641J)
Prereq: 3.15 or 6.08; 8.04 or 8.211
Year: G (1, 2) 0–8–4
Experimental investigations on the physical properties of materials closely related to current research; brief lectures on the basic theories and experimental methods. Experiments in areas of X-ray diffraction, galvanomagnetic effects, superconductivity, ferroelectricity, crystal growth, infrared absorption, Mössbauer effect, thermal properties, magnetic resonance, dielectric properties, carriers in semiconductors, elastic constants, defect structures. *Moss, A. C. Smith*

3.41 ***Physics of Solids I***
Prereq.: 8.03T
Year: G (1) 4–0–8
Physical and mathematical concepts important in quantitative theories of solid-state phenomena. Lectures including rigorous treatments of the following general areas: classical mechanics, electromagnetic theory, and statistical mechanics. Some specific topics: Lagrange's and Hamilton's equations, Maxwell's equations, optical properties of metals, Schrödinger's equation, matrix method, variational principle, and Fermi-Dirac statistics. *K. H. Johnson, Averbach*

3.42J ***Physics of Solids (A)***
(Same subject as 6.651J)
Prereq.: 3.41; or 6.03 and 8.211
Year: G (1) 3–1–8
First term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Emphasis on mathematical methods and physical models which have proven to be generally useful in obtaining

quantitative descriptions of physical quantities. Student use of a computer console to solve quantitative problems; no programming experience necessary. Topics include: diffraction of X rays, electrons, and neutrons by solids; periodic structures and reciprocal space; lattice dynamics, normal modes and phonons; quantum statistics; electron states in solids, Bloch waves and energy bands; perturbation theory; classification of solids. *Kaplow, A. C. Smith*

3.43J *Physics of Solids (A)*
(Same subject as 6.652J)
Prereq.: 3.42J or 6.651J
Year: G (2) 3–1–8
Second term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Topics: dynamics of electrons in solids, effective mass theorem; transport phenomena, electrical conductivity; magnetic phenomena, angular momentum and spin; paramagnetism, diamagnetism, ferromagnetism; interaction of radiation with solids, optical properties, resonance phenomena. *Sellmyer, A. C. Smith*

3.50 *Thermodynamics in Process Metallurgy* (A)
Prereq.: 3.03, 3.20
Year: G (1) 3–0–6
Advanced treatment of the thermodynamic properties of metallurgical systems with emphasis on molten metals, slags, and mattes. Reactions of molten iron, steel, and other metals with slags and gases. Problems in the refining and solidification of metals, and other selected topics. Use of computer time sharing in metallurgical problems. (*Not offered 1968-69. Alternate years.*) *Elliott*

3.51 *Process Metallurgy* (A)
Prereq.: 3.03
Year: G (2) 3–0–6
Study of integrated metallurgical processes. Application of the fundamental treatment of 3.03 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*

3.52 *Dynamic Behavior of Metallurgical Systems* (A)
Prereq.: 3.01, 18.034
Year: G (1) 3–0–6
Interpretation of the behavior of metallurgical systems by application of the methods of process analysis and control theory. Modeling of systems and exploration of their characteristics with digital and analog computers. (*Alternate years.*) *Elliott*

3.53 *Electrochemistry* (A)
Prereq.: 3.01
Year: G (1) 2–0–4
Development of principles underlying galvanic cells, conductance, electrode kinetics, double layers; with assignment of typical numerical problems. Discussions of application to practice, including electro-analysis, electroplating, electrowinning, primary and secondary cells, electrophoresis. *Uhlig*

3.54 *Corrosion* (A)
Prereq.: 3.01
Year: G (2) 3–0–5
Quantitative application of electrochemical principles to corrosion reactions. Effect of metallurgical factors; atmospheric, soil, or aqueous environments; oxidation and tarnish; stray currents; cathodic and anodic protection; metallic, inorganic and organic coatings; inhibitors; treatment of water and steam systems; selection of materials. *Uhlig*

3.55 *Mineral Engineering*
Prereq.: 3.08T
Year: G (1) 2–0–4
Application of the principles discussed in 3.08 to mineral engineering problems. Emphasis on the case system of study of actual operations. Sample topics: magnetic concentration of taconites and formation of quality pellets for iron smelting; flotation of porphyry copper ores and recovery from the copper concentrates of molybdenite by-product; manufacture of sulphuric acid from smelter gases and its fixation by phosphate-rock concentrates to obtain various phosphatic fertilizers; leaching recovery of uranium and gold from low-grade ores; recovery of gem diamonds from alluvial or beach deposits; flotation and leaching recovery of potassium chloride from sylvinite ores. *Gaudin*

3.60 *Physical Ceramics II* (A)
Prereq.: 3.07
Year: G (2) 3–0–6
Effects of composition and structure on properties of crystalline ceramics. Anisotropy, tensor representation of properties, and effect of crystal symmetry. Application to piezoelectricity and elastic properties of ceramics. Propagation of elastic waves in crystals. Discussion of thermal conductivity, heat capacity, magnetic and ferroelectric behavior, with emphasis on real materials and influences of microstructure. *Wuensch*

3.61 *Physical Ceramics III* (A)
Prereq.: 3.60
Year: G (1) 3–0–6
Structure of amorphous solids. Effects of composition and thermal history on properties of glasses, including discussions of recent publications. *Uhlmann*

3.62T *Electrical and Optical Properties of Ceramics (A)*
Prereq.: 3.07, 3.60
Year: G(1) 3–0–6
Discussion of the electrical and optical properties of crystalline ceramics in terms of defect chemistry, band theory and transport theory. Emphasis on effects of composition and microstructure on the properties of real materials. *Mogab*

3.63 *Ceramic Processes* (A)
Prereq.: 3.06 or 3.07; 3.20; 3.21
Year: G (2) 3–0–6
Phase equilibria and ceramic phase diagrams applied to microstructure development. Description and analysis of various kinetics of microstructure development and ceramic forming processes. Critical aspects of processing as related to property development and control. *Coble*

3.64 *Special Problems in Ceramics* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Advanced work in this field. Lectures, conferences, assigned readings, and laboratory work. *Kingery*

3.65 *Ceramics Seminar* (A)
Prereq.: 3.06 or 3.07
Year: G (1, 2) 1–0–2
Individual talks followed by group discussion on current research and developments in ceramics by staff, students, and invited speakers. *Uhlmann*

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3.70 *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*

3.701T *Properties of Metals*
Prereq.: ——
Year: G (2) 4–1–6
Properties of metals with reference to materials used in ship construction. Microstructure, processing, heat treatment, joining and corrosion resistance of non-ferrous and ferrous metals. (*Primarily for selected officers of the U. S. Navy and Coast Guard.*) *Floe*

3.72J *Nuclear Fuels* (*A*)
(Same subject as 22.72J)
Prereq.: 3.13 or 3.14 or 22.71
Year: G (1) 2–0–6
Behavior of nuclear fuels and fuel element cladding materials in reactor cores. Experimental observations and theory of radiation damage to metals and ceramics of practical interest. Processes for fabricating fuel elements and fuel assemblies; fuel fabrication costs. Recent developments of advanced reactor core materials. (*Alternate years. Not offered 1968–69.*) *Ziebold*

3.721J *Radiation Damage in Crystalline Solids* (A)
(Same subject as 22.721J)
Prereq.: 3.13 or 3.14 or 22.71
Year G (1) 2–0–6
Theory of atomic displacements, cascades, and spike phenomena produced in metals and ceramics by high-energy radiation bombardment. Recovery of damage related to mobility and structure of crystalline imperfections. Discussion of radiation damage experiments of technological importance and basic experiments designed to test the theory of damage production and recovery. Consideration of special problems associated with damage in fissionable materials. Brief outline of the role of materials in nuclear reactor design. (*Alternate years.*) *Ziebold*

3.73 *Applications of Digital Computers* (A)
Prereq.: ——
Year: G (1) 3–1–4
The theory and practice of computer programming and digital computation techniques with examples of analysis useful in research. Series expansion, integration, table look-up and interpolation, iterative solutions, matrix operations, least square fitting, Fourier transforms, differential equations, relaxation procedures, policy improvement, Monte Carlo methods. IBM 360/65 computer used. *Kaplow*

3.74 *Statistical Thermodynamics of Materials* (*A*)
Prereq.: 3.01
Year: G (2) 3–0–6
Introduction to statistical mechanics and thermodynamics, kinetic theory, elementary quantum statistics, crystal thermodynamics, and the Boltzmann transport equation. Application to problems in chemical kinetics and electronic behavior of solids. (*Not offered 1968–69.*) *R. M. Rose*

3.75 *Structure and Properties of Interfaces* (A)
Prereq.: 3.01
Year: G (1) 3–0–6
Examination of the salient physical and chemical characteristics of surfaces from a macroscopic and atomistic viewpoint. Emphasis on the thermodynamic description of systems with plane and curved surfaces, the kinetics of surface processes, atomic and electronic configuration of interfaces and the electrochemical nature of phase boundaries. Application of principles to wetting and spreading, adhesion, electrode processes, measurement of surface tension of solids. Discussion of the role of surfaces in nucleation, crystal growth, catalysis. *de Bruyn*

3.76J *Electronic Materials* (A)
(Same subject as 6.64J)
Prereq.: 3.15; or 6.02 and 6.13; or 6.02 and 6.341
Year: G (2) 2–0–6
Various aspects of electronic materials such as preparation, purification, crystal growth, crystal structure, characterization, electronic properties, band structure and device applications. Special emphasis on relationships between structural characteristics, atomic bonding and physical properties in classes of materials such as elemental and compound semiconductors, thermoelectrics and superconductors. Extensive rather than intensive coverage. *Gatos, Witt*

4. *Architecture*

4.011 *Graphics Laboratory I*
Prereq.: ——
Year U (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: U (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*

4.013 *Graphic Composition*
Prereq.: 4.032
Year: U (1) 2–4–6
Study of visual abstraction based on graphic images. Study projects centering on aesthetics of surfaces, visual counterpoint, optical illusions, pictorial motion, compositions of positive and negative area relationships, the concrete and the amorphous, analogous and complementary, exploration of symbolic images. Objective: realization of visual meaning and composition through synthesis of graphic imagery. *Preusser*

4.021 *Visual Design Problems I*
Prereq.: ——
Year: U (1, 2) 2–6–0
Studio participation in problems of visual invention, organization, and expression. Development of visual awareness, imagination, and creative insight focused upon subjective-qualitative values. Study of the visual elements and their organization approached analytically for the purpose of stimulating visual perception and clarifying the language of visual arts. Experimentation in the application of materials, tools, and processes unique to each student's professional field is encouraged as a means of gaining confidence and ability to create visual form. *Preusser*

4.022 *Visual Design Problems II*
Prereq.: 4.021 or 4.051T or 4.071
Year: U (2) 2–6–0
Principles of visual organization applied to two- and three-dimensional design with emphasis on inventive use of media. Studio procedures individually directed, enabling the student to formulate and execute independent projects. Opportunity to explore new materials, tools, and techniques of photography and conventional media of painting and sculpture for the purpose of visual expression. Critiques to clarify studio work and seminars to investigate relationships between art, science, and technology in restructuring the visual environment.
Preusser

4.023 *Visual Design Projects*
Prereq.: ——
Year: U (2) 2–4–6
Investigative analysis of the visual potential inherent in science and technology. Inventive manipulation of tools, materials and techniques as a means of broadening the basis of visual thinking and clarifying the interaction between concept, media, and design principles. Primary objective: to innovate artistic idioms which may enrich physical environment. Projects involving experimental application of new materials and techniques to specific problems of visual form with special attention given the relationship of art to architecture and the urban environment. *Preusser*

4.031 *Form and Design I*
Prereq.: ——
Year: U (1) 2–4–6
Study of the visual elements of form to understand the processes of form synthesis. Studio experiments and lectures on proportion, shape, rhythm, visual quality of materials and three-dimensional composition. Emphasis on imagination and visual sensitivity directed to enlarge the individual's ability to create an aesthetic form.
Filipowski

4.032 *Form and Design II*
Prereq.: 4.031
Year: U (2) 2–4–6
Three-dimensional experiments and lectures on the organization of quantities, unit to volume relationships, modularity and form, volume and structure, surface structure of volume, space composition, point, line, plane composition, and sculptural composition. Emphasis on architectonic and sculptural aesthetic of form.
Filipowski

4.033 *Form and Color I*
Prereq.: 4.031
Year: U (1) 2–0–4
Examination of color in natural form followed by experiments involving the color and form relationship to proportions, percentages, repetition, directions, quantity organization, structural order, angle position, and volume composition. A study to gain knowledge of color for the refinement of architectural form. *Filipowski*

4.034 *Form and Color II*
Prereq.: 4.032
Year: U (2) 2–4–6
Study of color in relation to visual refinements of form — hue, value and chroma relationship from the general to the particular. Sequence of study projects involving color and area, texture, periodic patterns, random configurations, color depth, black and white, visual vibrations, color and natural form, volume, structure, motion, object and the color environment, and the visual influence of color on spaces. *Filipowski*

4.04 *Light and Color*
Prereq.: 4.031
Year: U (2) 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*

4.041 *Light and Color I*
Prereq.: 4.032
Year: U (1) 2–4–6
Study of psychological and physiological phenomena of light and color. Lectures, demonstrations and exercises to determine the vocabulary of these elements, their relevance to communication and use in creating visual form. Utilization of photography to analyze light as a form-giving element and creative tool. Advances in techniques for generating light and producing color investigated and utilized in studio work. *Kepes*

4.042 *Light and Color II*
Prereq.: ——
Year: G (2) 0–9–11
Content same as 4.04. *Kepes*

4.051T *Creative Photography I*
Prereq.: ——
Year: U (1, 2) 2–6–0
Exposure of the beginning student to photographic technique involving camera, light, film, chemicals and paper. Development of a sense for or composition through visual exercises and analysis of photographic images. Development of the student's awareness of his own way of seeing through exposure to many photographic images — his own, his instructors', exhibited gallery prints, and those of our mass media. (*Limited enrollment.*) *G. C. Thomas*

4.052T *Creative Photography II*
Prereq.: 4.051T
Year: U (1, 2) 2–6–0
Examination of the photograph as a visual statement about the human condition, in which moments related to time are converted into images related in space. Lectures and class discussion on technical, psychological, and graphic-layout problems followed by ten weeks of individual photographic projects resulting in completed visual or audio-visual presentations. (*Limited enrollment.*)
G. C. Thomas

4.053T *Evaluating Photography*
Prereq.: 4.031 or 4.051T
Year: U (1, 2) 3–0–5
Introduction to an existential basis of criticism for photography. Investigation of public response to photographs and critical standards. Photography that evokes as well as communicates. Involvement with existing images instead of making photographs. (*Also open to exchange and special students with design and humanities backgrounds by consent of instructor. Limited enrollment.*) *M. White*

4.054 *Advanced Photography*
Prereq.: 4.032
Year: U (1, 2) 2–4–6
Application of both the recording and transforming powers of the camera to the problems of direct contact with subject matter and the indirect use of photometaphor for the varied purposes of visual evocation. (*May be repeated for credit. Limited enrollment.*) *M. 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.

4.055 ***Problems in Photography***
Prereq.: ——
Year: G (1, 2) *Arr.*
Theoretical and practical studies in seminar, studio, and field to introduce and develop the full scope of photography as craft, art, and public medium. (*Limited enrollment.*) *M. White*

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*

4.071 ***Painting***
Prereq.: ——
Year: U (1) 2–6–0
Practice in the art of painting coordinated with theory related to contemporary concepts in the light of historical development. Language of art with emphasis on structure and content advanced by lectures and demonstrations as framework for studio activity. Creative capacity and analytical ability challenged by studio and seminar participation. Manipulation of the visual elements in painting utilizing principles of organization to realize individual expression through pictorial means. Primary goal: experiencing the artist's process and understanding visual values and meaning of art in culture. *Preusser*

4.081 ***Plastic Composition***
Prereq : 4.032
Year: U (1, 2) 2–4–6
Study of plastic sculptural form based on continuity of surfaces, synthesis of diverse geometries, group form relationships, object and the landscape, and the optimum three-dimensional relationship of the object. Studies directed toward inventiveness and meaning of sculptural form. *Filipowski*

4.121 ***Architectural Design***[1]
Prereq.: ——
Year: U (1) 2–5–5

4.122 ***Architectural Design***[1]
Prereq.: 4.121
Year: U (2) 2–5–5
Establishment of basic attitudes to architectural organization and its reflection in form. Small-scale problems whose imposed conditions of site, program, and building system emphasize the interrelationship of fundamental elements in the pattern of decision making that constitutes design. Presentations fully developed in drawings and models. *M. K. Smith*

4.131 ***Architectural Design***[1]
Prereq.: 4.122
Year: U (1) 0–6–6

4.132 ***Architectural Design***[1]
Prereq.: 4.131
Year: U (2) 0–6–6
Development of awareness of the principal issues facing the contemporary architectural designer and the range of possibilities available for effective satisfaction of common environmental needs. Work on separate building units with definitely stated use patterns with 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

4.143 ***Architectural Design*** **(A)**
Prereq.: 4.132, 4.32
Year: G (1) 0–12–8

4.144 ***Architectural Design*** **(A)**
Prereq.: 4.143
Year: G (2) 0–12–8
Study of more intensive and extended space uses, the grouping of buildings, buildings of multi-story 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 installations associated with them. *Staff*

4.151 ***Architectural Design***[1]
Prereq.: 4.142
Year: U (1) 0–12–8
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 Bachelor in Architecture thesis project and determination of the requirements and conditions to be met in the solution. Independent work under the guidance of the Thesis Advisors. *Staff*

4.155 ***Architectural Design*** **(A)**
Prereq.: 4.144
Year: G (1) 0–12–8
Same content as 4.151. *Staff*

4.157 ***Thesis Research*** **(A)**
Prereq.: 4.144
Year: G (1, 2) 0–6–0
Selection of subject and site for graduate Bachelor in Architecture thesis project and determination of the requirements and conditions to be met in the solution. Independent work under the guidance of the Thesis Advisors. *Staff*

4.161 ***Architectural Design*** **(A)**
Prereq.: 4.151
Year: G (1) 0–15–20
Advanced projects focused on development of a theme proposed by the section instructor, these themes being statements of professional opportunities and challenges of the next generation. Selection of sections and themes insofar as practicable by the student. Section A: exploration of the relationship between urban developments and prototype buildings. Section B: search for forms and methods to deal architecturally with the new collective urban environment. Section C: research and education on urban housing for developing countries. *Catalano, Caminos*

[1] ***Note about the subjects in Architectural Design***
The undergraduate sequence in Architectural Design is a cumulative program. Its successful completion by the student is subject to the evaluation of the staff independently of formal grades accumulated.

4.17, 4.171 *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*

4.19 *Special Problems in Architectural Design* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*

4.191 *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*

4.30 *Structures I*
Prereq.: 8.02, 18.02
Year: U (2) 3–3–6
Introduction to the static behavior of structures. Determination of loads, deformations of determinate and indeterminate structures. Definitions of stress and strain at a point with an introduction to material behavior. Applications to stress distributions and deflections of slender elements in twisting and bending. Considerations of stability of structures in both elastic and plastic situations. The qualitative use of models to illustrate basic concepts as well as for solution of complex problems. Laboratory work giving students opportunity to produce creative designs for solving structural problems, with execution of these designs by building models and testing them. *Groisser*

4.31 *Structures II*
Prereq.: 4.30
Year: U (1) 2–2–4
Comparative study of strength, stiffness, and stability of building elements of wood, metals, and reinforced concrete. Principles of connections in building elements. Study of structural systems including framed structures, pinned-truss structures, and two- and three-dimensional surface structures. Detailed study of systems using sawn timbers, laminated timbers, and plywood. *Le Messurier*

4.32 *Structures III*
Prereq.: 4.31
Year: U (2) 2–2–4
Detailed study of design of metal structures. Simple frames, welded continuous frames, two- and three-dimensional trusses, plate girders, and cable structures. Methods of statically indeterminate analysis. *Le Messurier*

4.33 *Structures IV*
Prereq.: 4.32
Year: U (1) 2–2–2

4.331 *Structures IV* (A)
Prereq.: 4.32
Year: G (1) 2–2–2
Detailed study of design of reinforced concrete structures. Floor systems, continuous frames, shell roofs, and plate systems. Principles of prestressed and precast concrete systems. *Staff*

4.34 *Structures V*
Prereq.: 4.33
Year: U (2) 2–0–4

4.341 *Structures V* (A)
Prereq.: 4.331
Year: G (2) 2–0–4
Special structural problems. High-rise buildings including design for wind forces. Long-span roof structures. Optimum design of structural elements and systems. Application of electronic computers to planning and analysis of building structures. *Staff*

4.402 *Building Process*
Prereq.: ——
Year: U (2) 3–3–6
Principal building systems as affected by environmental and legal conditions, materials, and industrial constraints. Interrelationships among the parts of the system. Fundamental systems of enclosure, load distribution and environmental control; air, heat, light, sound. Assembly processes and principles of project control. Problems, projects, and field trips to illustrate principles. *Dietz*

4.42T *Materials*
Prereq.: 1.02
Year: U (2) 3–2–3
Emphasis on newer materials and combinations. Development of properties and applications from fundamental structure of materials. Plastics and other polymeric materials. Engineering adhesives and principles of bonding. Wood derivatives and bonded structures. Ceramics. Glass. High-performance masonry. Metals and alloys. Composites of several materials: fiber-reinforced, laminates, and sandwiches. Principles of combined behavior. Deterioration of materials, protection against attack. *Dietz*

4.43 *Environmental Control — 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.
R. B. Newman

4.431 *Special Problems in Architectural Acoustics* (A)
Prereq.: 4.43
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.
R. B. Newman

4.601 *Topical Studies in the History and Theory of Art*
Prereq.: ——
Year: U (1) 3–0–5
Painting, sculpture, and architecture from pre-history to the present. The different motivations for visual art, its cultural implications, the various forms it has assumed, and the means of its production investigated relative to time and place. Theories of art and art history and methods of criticism presented and analyzed in lectures and discussions, and on visits to Boston area museums.
Krauss

4.602 *Introduction to Modern Art*
Prereq.: ——
Year: U (2) 3–0–5
Painting and sculpture from the late eighteenth century to the present. An investigation of the theoretical basis for such different styles as neo-Classicism, Romanticism, Impressionism, Cubism, Constructivism, Surrealism, etc., and including the recent events of Abstract Expressionism and its aftermath. Presented both historically and topically. Problems of interpretation and criticism.
Krauss

(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.

4.603 ***Painting and Sculpture in the Middle of the Nineteenth Century***
Prereq.: ——
Year: U (1) 3–0–5
Art and artists in Paris around 1850, preceding the formulation of Impressionism in the late sixties and seventies. Manet, Degas, Pissarro, Monet, Renoir, the early Cézanne — their background and their achievements, their continuity into the eighties and importance for later phases of modern art. Special emphasis on nineteenth century color theory. *Staff*

4.604 ***Modern Art from Post-Impressionism to Cubism***
Prereq.: ——
Year: U (2) 3–0–5
Cézanne, Gauguin, Van Gogh, and Seurat presented against a background of Impressionism and other nineteenth century styles. Their relationship to the Synthetist, Nabis, and Symbolist groups. Required readings from letters and other writings by the artists, their artist and writer friends, and their critics. *W. V. Andersen*

4.605 ***Painting in the Twentieth Century***
Prereq.: ——
Year: U (1) 3–0–5
Cubism, Futurism, Constructivism and other phases of early twentieth-century art during which the theories, styles, and attitudes of contemporary art were formulated. Dadaism, Surrealism, and other intermediate phases leading to Abstract Expressionism in New York. Post-Painterly Abstraction styles, Pop Art, and the recent Optical Art Movement, considered both historically and critically. *W. V. Andersen*

4.606 ***Sculpture in the Twentieth Century***
Prereq.: ——
Year: U (2) 3–0–5
Development, against a background of Rodin and late nineteenth century sculpture, of the trends leading to the present day situation. Special emphasis on Maillol and the "large-figure" style, Brancusi and direct carving; cubist, futurist, and constructivist sculpture. One-third of the subject devoted to American sculpture since 1930. (*Not offered 1968–69.*) *W. V. Andersen*

4.607 ***Twentieth-Century Art Theories***
Prereq.: ——
Year: G (1 or 2) 3–0–5
Seminar on the origin and interaction of the movements which established the formal vocabulary of most twentieth-century art. (*Open also to advanced undergraduates with consent of instructor.*) *W. V. Andersen*

4.608 ***Symbolism in Modern Art***
Prereq.: ——
Year: G (1 or 2) 3–0–5
Seminar on selected topics in the analysis of the content and meaning of modern art. (*Open to qualified students with consent of instructor. Not offered 1968–69.*)
W. V. Andersen

4.61 ***Architecture in the Ancient World***
Prereq.: ——
Year: U (2) 3–0–5
Analysis of role of mass, space, structure, light, surface, and related social, political, and economic factors in architecture and urban design from prehistory through Roman times. (*Not offered 1968–69.*) *Millon*

4.62 ***Architecture 1400-1750***
Prereq.: ——
Year: U (1) 3–0–5
Same as 4.61, but covering the period from the beginning of the Renaissance to the end of the Rococo. *Millon*

4.621 ***Origins of Contemporary Architecture in the Eighteenth Century* (A)**
Prereq.: 4.601 or 4.62 or 4.64
Year: G (1) 3–0–5
Seminar surveying the principal works of architecture and major theoretical statements of eighteenth-century architects and writers in order to define, understand, and examine the origins of contemporary theoretical positions. (*Not offered 1968–69.*) *Millon, S. Anderson*

4.63 ***Architecture in the Middle Ages***
Prereq.: ——
Year: U (2) 3–0–5
Selected buildings and urban complexes from the time of Rome's conversion to Christianity to the beginning of the Renaissance. Special attention given to the influence on the builders of architectural traditions as well as significant religious, social, political and economic factors. (*Not offered 1968–69.*) *S. Anderson*

4.64 ***Architecture from 1750 to the Present***
Prereq.: ——
Year: U (2) 3–0–5
Same as 4.63, but covering the period from the mid-eighteenth century to the present. (*Not offered 1968–69.*)
S. Anderson

4.641 ***Modern Architecture in Germany from 1895 to the Bauhaus* (A)**
Prereq.: 4.601 or 4.64
Year: G (1) 3–0–5
Art and architecture in Germany from the late nineteenth century to the time of the Nazi repression of modern art. Intensive study of the men, the works, and the controversies from which the European "modern movement" emerged, leading in turn to the transformation of American architecture. *S. Anderson*

4.65 ***Studies Toward a Theory of Architecture* (A)**
Prereq.: ——
Year: G (1) 3–0–5
Seminar with the intent to stimulate thought about our contemporary theoretical position. Reports by seminar members either in the context of, or in criticism of, the thesis of the seminar. *S. Anderson, Millon*

4.66 ***Criticism of Architecture* (A)**
Prereq.: ——
Year: G (2) 3–0–5
Seminar surveying the various approaches (social, environmental, economic, compositional, structural, functional, etc.) and bases for the criticism of architecture. Principal emphasis on formal bases of criticism. History of criticism, relation of criticism and history, value of criticism to the profession, criticism as a means of achieving quality in architecture, and criticism as a rational and emotional response to architecture.
Millon, S. Anderson

4.67 ***History of Urban Form* (A)**
Prereq.: ——
Year: G (2) 3–0–5
History of the city as an architectural form. Study of the physical growth of cities as an expression of a developing social structure as well as with reference to artistic ideals. *Staff*

4.68 ***Selected Topics in the History of Art and Architecture* (A)**
Prereq.: 4.601, 4.602; or 4.61, 4.62, 4.63, 4.64
Year: G (1) *Arr.*

4.69 ***Selected Topics in the History of Art and Architecture* (A)**
Prereq.: 4.601, 4.602; or 4.61, 4.62, 4.63, 4.64
Year: G (2) *Arr.*
Special topics in the history of art and architecture, to be varied at the discretion of the instructor. *Staff*

4.681 ***Theory and Method in the History of Art and Architecture***
Prereq.: ——
Year: U (1, 2) 3–0–5
Selected research with written report. Intended primarily to prepare the student for graduate studies. (*Open only to advanced students in Program 4.*) *Staff*

4.69 ***See 4.68 above.***

4.701J ***Architectural Communication***
(Same subject as 2.701J)
Prereq.: ——
Year: U (1, 2) 4–2–2
Communication with self (visualization), with others (presentation), and with machines (manipulation). Introduction to orthography, perspective, projective geometry, matrix algebra, descriptive geometry, diagrams, and models. Relationship between communication media and process or product. *Negroponte, Coons*

4.704 ***Computer Aided Urban Design*** **(A)**
Prereq.: ——
Year: G (2) 3–0–6
A workshop subject with students embarking on research projects of their choosing within the context of architect-machine communication as an aid to the design of urban environments. Special emphasis on machine partnership and programs of evolution. (*Note: Experience in programming a necessary prerequisite.*) *Negroponte, Groisser*

5.
Chemistry

5.01 ***Chemistry***
Prereq.: ——
Year: U (1, 2) 5–0–7
Properties of solids and crystals — ionic and covalent, determination of crystal structure, properties of solids. Properties of liquids — ideal and non-ideal solutions and their properties, solubility, temperature effects. Properties of gases — kinetic theory of gases, imperfect gases, transport properties. Electronic structure — Bohr model, significance of energy levels. The chemical bond — diatomic molecules, bond energies, rotation and vibration spectra, polyatomic molecules, bond lengths, bond angles. Chemical kinetics — rate laws, temperature effects, application to reaction mechanism. *Staff*

5.03 ***Principles of Inorganic Chemistry I***
Prereq.: 5.41; 5.63 or 8.04
Year: U (2) 3–0–9
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 non-transition elements. *Cotton, Davison*

5.04 ***Principles of Inorganic Chemistry II***
Prereq.: 5.03
Year: U (1) 2–0–4
Theory and descriptive material relating to the heavier elements and the transition elements. Special emphasis on ligand field theory. *Cotton*

5.065 ***Advanced Inorganic Chemistry*** **(A)**
Prereq.: 5.03
Year: G (2) 3–0–6
Extended treatment of some special topics of current interest in modern inorganic chemistry, organometallic compounds, and hydrides; treatment in terms of modern electronic and structural theory. *Seyferth*

5.067 ***Chemical Applications of Group Theory*** **(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. (*Not offered 1968-69.*) *Cotton*

5.09 ***Radiochemistry*** **(A)**
Prereq.: 5.62
Year: G (1) 3–0–6
Introduction to nuclear science of interest to chemists. Radioactivity, nuclear structure and reactions, radiation detection and measurement, preparation and separation of radionuclides, techniques and applications in nuclear chemistry. *Gordon, Walters*

5.091 ***Radiochemistry Laboratory*** **(A)**
Prereq.: 5.09
Year: G (1) 0–3–3
Laboratory study of special topics including radiochemical analysis, the fission process, and the reactions following nucleogenesis. *Gordon, Walters*

5.092 ***Special Topics in Nuclear Chemistry*** **(A)**
Prereq.: 5.09
Year: G (2) 1–0–3
Detailed discussion and problems on various topics of special interest to research students in nuclear chemistry, including nuclear fission, compound-nucleus reactions, nuclear models and structure, etc. *Gordon*

5.14 ***Analytical Chemistry***
Prereq.: 5.41
Year: U (1) 4–4–4
Introduction to chemical and instrumental analytical techniques. Electrochemical methods, separation principles and applications to the determination of inorganic constituents and organic functional groups. Introduction to the statistical interpretation of data. Laboratory coordinated with lecture. (*Not offered after 1968-69.*) *Hume*

5.193 ***Equilibrium and Separation Processes*** **(A)**
Prereq.: 5.14, 5.62
Year: G (2) 3–0–6
Consideration of equilibrium principles pertaining to analytical methods based on chemical reactions, in aqueous and non-aqueous solvents. Separation methods including liquid-liquid partition, ion exchange, volatilization, precipitation and zone refining. Emphasis on multistage partitioning processes and relevant rate theories. (*Not offered 1968–69.*) *Hume*

(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.

5.194 ***Design and Analysis of Experiments*** **(A)**
Prereq.: 5.14
Year: G (2) 2–0–4
Principles and applications of statistical design and analysis in chemistry and related fields. Significance testing, analysis of variance, correlation and regression. Sampling, sequential analysis, block designs, factorial design, fractional replication and determination of optimum conditions. (*Not offered 1968–69.*) *Hume*

5.195 ***Interpretive Spectroscopy*** **(A)**
Prereq.: 5.42, 5.63
Year: G (1) 3–0–6
Discussion of spectrometric techniques and their application to the identification of chemical compounds. Major emphasis on complementary use of infrared, nuclear magnetic resonance and mass spectrometry. Discussion of other techniques including ultraviolet spectrometry and molecular emission spectra. *Biemann, Hercules*

5.20 ***Laboratory Problems in Chemistry***
Prereq.: ——
Year: U (1, 2) 1–3–2

5.21 ***Laboratory Problems in Chemistry***
Prereq.: ——
Year: U (1, 2) 1–6–5
Laboratory work with guidance of the chemistry department staff. Projects of chemical nature involving the determination of properties of a system or the reactivity of combinations of systems. Available topics: ΔS of a reaction by temperature dependence of e.m.f., ΔH's by calorimetry, colligative properties of liquids, mass spectrometry, chemical kinetics, X-ray interpretation and model building, construction and use of a photoelectric calorimeter and adaptation for optical rotation experiments, simple harmonic oscillator model, dipole moment by heterodyne beat method, chromatography, gas diffusion, construction of a simple NMR detector, quantum yield and actinometry of a photochemical reaction, organic and inorganic syntheses, radiochemical studies and investigation of the accuracy of analytical methods. Topics for organic-biochemical specialization: synthesis, enzyme kinetics and chromatography. (*Enrollment limited. Third and fourth year students must consult instructor before registering.*) *Term 1: Steinfeld*
Term 2: Hercules

5.31 ***Introduction to Chemical Experimentation***
Prereq.: 5.01, *5.41*
Year: U (1) 2–8–2
Introduction to the methods of experimental chemistry which emphasizes modern procedures for the preparation, isolation, purification, analysis, and characterization of substances, solid and liquid. *Staff*

5.32 ***Intermediate Chemical Experimentation***
Prereq.: 5.31, *5.42, 5.60*
Year: U (2) 2–8–2
More advanced experimental work with emphasis on equilibria, thermochemical measurements, and measurements of properties of gases. Introduction to the construction of simple apparatus, to simple electrical measurements, to the measurement and interpretation of infrared, visible, and ultraviolet spectra, and to chromatographic separations. *Staff*

5.33 ***Advanced Chemical Experimentation***
Prereq.: 5.32, *5.63*
Year: U (1) 2–12–4
Advanced experimentation with particular attention to the syntheses of compounds, the measurement of kinetic phenomena, and the use of modern instrumentation. Some of the topics to be included: interpretation of nuclear magnetic resonance spectra and mass spectra, use of electronic equipment, application of computers to the solution of chemical problems, and use of the chemical literature. (*Not offered until 1969–70.*) *Staff*

5.341 ***Introduction to Research in Synthetic Chemistry***
Prereq.: *5.03*, 5.33, *5.62*
Year: U (2) 2–12–4
Project-oriented laboratory in which the methods and approaches of the contemporary synthetic chemist are illustrated by the preparation of relatively complex inorganic, organic, and organometallic substances. Full use of the techniques and instrumentation employed in the modern research laboratory. (*Not offered until 1969–70.*) *Staff*

5.342 ***Introduction to Physico-chemical Research Methods***
Prereq.: *5.03*, 5.33, *5.62*
Year: U (2) 2–12–4
Introduction to methods of physico-chemical measurement employed in contemporary research, with project work in such areas as atomic and molecular spectroscopy, transport properties of gases, molecular dynamics and interactions, electric and magnetic properties, properties of macromolecules, solid-state structure and properties, and surface phenomena. (*Not offered until 1969–70.*) *Staff*

5.41 ***Organic Chemistry I***
Prereq.: ——
Year: U (1) 4–0–8
Introduction to the chemistry of carbon compounds. Survey of the principal classes of aliphatic and aromatic compounds and their reactions. *Kemp*

5.42 ***Organic Chemistry II***
Prereq.: 5.41, 5.31
Year 4–0–8
Study of organic reactions, with emphasis on the relation between structure and reactivity. *F. D. Greene*

5.428 ***Introduction to Organic Research***
Prereq.: 5.53T
Year: U (2) 2–9–1
Instruction in the use of current research techniques for the identification, separation, and synthesis of organic compounds. (*Not offered 1968–69.*) *House*

5.51T ***Advanced Organic Chemistry: Synthesis*** **(A)**
Prereq.: *5.53T*
Year: G (1) 3–0–6
Organic reactions and the methods by which they are applied to synthetic problems in organic chemistry.
W. R. Moore

5.53T ***Molecular Structure and Reactivity*** **(A)**
Prereq.: 5.32, 5.42
Year: G (1) 3–0–6
Introduction to the theoretical interpretation of reactivity, reaction mechanisms, and molecular structure of organic compounds. Applications of spectroscopy to the determination of structure. *Whitesides*

5.54T ***Physical Organic Chemistry*** **(A)**
Prereq.: 5.53T
Year: G (2) 3–0–3
Mechanisms of representative organic reactions in homogeneous liquid systems. Kinetic and other physical methods useful in studying organic reactions. Types of experimental evidence upon which current theoretical interpretations of reactivity are based. *Swain*

5.55T ***Organic Chemistry: Natural Products*** **(A)**
Prereq.: 5.51T
Year: G (2) 3–0–3
The chemistry and physiological action of natural products. Methods of isolation; determination of structures and synthesis. *Büchi*

5.56 *Special Topics in Organic Chemistry* (A)
Prereq.: 5.51T, 5.53T
Year: G (2) 3–0–6
Advanced topics of special current interest. *Staff*

5.60 *Chemical Thermodynamics*
Prereq.: 8.01, *18.02*
Year: U (1, 2) 4–0–8
Basic thermodynamics — system, state of system, states of aggregation, state variables. Work, heat, first law of thermodynamics. Thermodynamic temperature scale. Second and third law of thermodynamics — Gibbs function, Helmholtz function, one-component systems. Concept of equilibrium-phase rule, colligative properties of solutions, homogeneous and heterogeneous equilibrium. Brief introduction to statistical thermodynamics. *Term 1: Garland*
Term 2: Gordon

5.613 *Physical Chemistry Laboratory I*
Prereq.: 5.60
Year: U (1) 0–4–2
Experimental topics in physical chemistry. Priority to Course v students. Limited to 75. (*Not offered after 1968–69.*) *Silbey, J. Lewis*

5.62 *Physical Chemistry*
Prereq.: 5.60; 5.63 or 8.04
Year: U (2) 4–0–8
Elementary kinetic theory and statistical mechanics; transport properties of gases and liquids; rates of chemical reactions. *J. Ross*

5.623 *Physical Chemistry Laboratory II*
Prereq.: 5.60
Year: U (2) 0–4–2
Continuation of 5.613. Priority to Course v students. Limited to 75. (*Not offered after 1968–69.*)
Bowers, Stephenson

5.63 *Physical Chemistry*
Prereq.: 8.02, 18.02
Year: U (1) 4–0–8
Introductory quantum chemistry: elementary atomic spectra; particles and waves; wave mechanics; atomic structure and the Periodic Table; valence theory; experimental methods of determining molecular structure; structure of crystals and liquids; photochemistry.
J. S. Waugh

5.68 *Kinetics of Chemical Reactions* (A)
Prereq.: 5.62
Year: G (2) 3–0–6
Experimental and theoretical aspects of advanced topics including: collision and transition state theories, homogeneous reactions in gas and liquid phases, enzymatic reactions, very fast reactions in solution, gas phase reactions in shock tubes and in molecular beams.
Amdur, Schimmel

5.70 *Introduction to Statistical Thermodynamics* (A)
Prereq.: 5.62
Year: G (1) 3–0–6
Review of classical thermodynamics and an introduction to elementary statistical mechanics, with applications to simple physical and chemical systems. *I. Oppenheim*

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. *Stephenson*

5.72 *Statistical Mechanics* (A)
Prereq.: 5.70, 5.73, 18.05
Year: G (2) 3–0–6
Principles and methods of statistical mechanics. Classical and quantum statistics, grand ensembles, fluctuations, molecular distribution functions, and other topics in equilibrium statistical mechanics. Advanced topics in thermodynamics, including irreversible processes. (*Not offered 1968–69.*) *I. Oppenheim, Ross*

5.73 *Introductory Quantum Mechanics I* (A)
Prereq.: 5.63, 8.03T
Year: G (1) 3–0–6
Fundamental concepts of quantum mechanics: wave properties, uncertainty principle, Schrödinger equation. Basic applications to: harmonic oscillator, hydrogen atom, WKB method. Perturbation theory and variation method. Pauli principle and spin. Introduction and use of operator and matrix methods. *Kinsey*

5.74 *Introductory Quantum Mechanics II* (A)
Prereq.: 5.73, 18.05
Year: G (2) 3–0–6
Continuation of 5.73. Permutation symmetry and angular momentum. Molecular dynamics. Time-dependent problems, radiation and matter. Scattering by a central field. Many-electron systems, approximate molecular and atomic wave functions. *J. S. Waugh*

5.76 *Molecular Spectra and Molecular Structure* (A)
Prereq.: 5.63, 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.
Steinfeld

5.80 *Special Topics in Chemical Physics* (A)
Prereq.: 5.70, 5.73
Year: G (1, 2) *Arr.*
Advanced topics of special or current interest. The specific areas announced in advance of each term. *Staff*

5.81 *Advanced Topics in Chemical Biophysics* (A)
Prereq.: 5.70, 18.05
Year: G (1 or 2) *Arr.*
Structures and properties of biopolymers. Statistical mechanics of biopolymers; matrix methods; conformational energies and configurational statistics; cooperative phenomena. Dynamics of biological processes; rates of enzymatic reactions; theory of chemical relaxation spectrometry with applications to biological reactions; rates of configurational changes in biopolymers. (*Offered occasionally. Consult instructor.*) *Schimmel*

5.82T *Advanced Topics in Solid State Chemistry* (A)
Prereq.: 5.70, 5.73
Year: G (1 or 2) *Arr.*
Selected topics from areas such as: structure of crystals, surface structure, symmetry groups, diffraction methods, lattice dynamics, order-disorder and magnetic phenomena, molecular motions in solids, relaxation phenomena, optical properties and exciton theory. (*Offered occasionally. Consult instructor.*) *Garland, Shoemaker, Silbey, Stephenson*

(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.

5.83 ***Advanced Topics in Statistical Mechanics and Kinetic Theory*** **(A)**
Prereq.: 5.70, 5.73
Year: G (1 or 2) *Arr.*
Fundamental concepts of the statistical mechanics of irreversible processes, and the kinetic theory of gases in relation to molecular interactions and collision dynamics. (*Offered occasionally. Consult instructor.*)
Amdur, I. Oppenheim

5.84T ***Advanced Topics in Spectroscopy and Quantum Mechanics*** **(A)**
Prereq.: 5.74
Year: G (1 or 2) *Arr.*
Topics varying from year to year, including magnetic resonance, beam spectroscopy, non-linear optics, kinetic applications, and quantum field theory. (*Offered occasionally. Consult instructor.*) *Lord, Silbey, Steinfeld, J. S. Waugh*

5.89 ***Special Problems in Chemistry for Undergraduates***
Prereq.: ——
Year: U (1, 2) *Arr.*
Program of study, either experimental or theoretical, to be arranged by the student and a departmental faculty member. Research for an undergraduate thesis may be arranged in this subject. *Irvine*

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.*) *Berchtold*

5.913 ***Seminar in Organic Chemistry*** **(A)**
Prereq.: ——
Year: G (1) 1–0–2
5.914 ***Seminar in Organic Chemistry*** **(A)**
Prereq.: ——
Year: G (2) 1–0–2
Discussion of current journal publications in organic chemistry by graduate students and staff members.
Berchtold

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.
Hercules

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. *Steinfeld*

5.941 ***Seminar in Inorganic Chemistry*** **(A)**
Prereq.: ——
Year: G (1) 1–0–2
5.942 ***Seminar in Inorganic Chemistry*** **(A)**
Prereq.: ——
Year: G (2) 1–0–2
Discussion of current research in inorganic and nuclear chemistry by graduate students and staff. *Seyferth*

Research **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Research for any of the advanced degrees in chemistry.
Staff

6.
Electrical Engineering

6.001 ***Elements, Systems and Computation I***
Prereq.: 8.02, 18.02
Year: U (1) 4–0–8
First part of a two-term sequence, 6.001–6.002, which may be substituted for 6.01 (or 6.013) and 18.034 by students majoring in electrical engineering. Interconnection of basic network and logic elements into signal and information-processing networks and systems for computation, communication, and control. Characterization and analysis of continuous and discrete systems by input-output and state relations. Memory-less and memory systems. Continuous systems, linear and elementary non-linear electrical networks, their differential equations and their solution; system function and impedance. Discrete systems, logic-gate networks and elementary finite state machines. *Dertouzos, S. J. Mason*

6.002 ***Elements, Systems and Computation II***
Prereq.: 6.001 or 6.01
Year: U (2) 4–0–8
Continuation of topics and philosophy of 6.001. High-order linear and non-linear dynamic systems and networks; their description by vector and matrix relations from the state-variable point of view. Elements of linear algebra. Analytical and algorithmic solutions for linear and non-linear algebraic, differential and difference equations. Numerical integration of differential equations. Convergence, stability, and error analysis of iterative algorithms. *Athans, Spann*

6.01 ***Introductory Network Theory***
Prereq.: 8.02, *18.034*
Year: U (1, 2) 4–0–8
6.013 ***Introductory Network Theory***
Prereq.: 8.02, *18.034*
Year: U (1, 2) 4–0–8
Fundamentals of network theory with emphasis on concepts and techniques which are important in and common to many areas of engineering and physics. Network model: Kirchhoff's laws; v-i characteristics of network elements; formulating equilibrium equations; Tellegen's theorem; energy and power. Time-domain analysis: state variables; formulating and solving state equations; natural frequencies and normal modes; impulse response and convolution integral. Frequency-domain analysis: system function; poles and zeros; frequency response curves; relations between forced response and natural behavior of networks; properties of system functions of networks; synthesis. *Huang*

6.02 ***Electronic Devices and Circuits***
Prereq.: 6.001 or 6.01
Year: U (1, 2) 4–0–8
6.023 ***Electronic Devices and Circuits***
Prereq: 6.013
Year: U (2) 4–0–8
Modeling of electronic control valves or power modulators, and analysis of non-linear circuits. Physical electronics of semiconductor junction devices, and the development of circuit descriptions for these devices; relation of electrical behavior to internal physical behavior, and limitations of circuit models. Analysis of signal-processing circuits which employ control valves, with examples chosen from switching circuits, negative resistance oscillators, incrementally linear amplifiers, and power amplifiers. *P. E. Gray*

6.03 ***Electromagnetic Fields and Energy***
Prereq.: 6.02; 8.03T; *18.05*
Year: U (1, 2, S) 4–0–8

6.033 ***Electromagnetic Fields and Energy***
Prereq.: 6.023; 8.03T; *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, quasi-static, and transverse electromagnetic waves; energy and power flow. The field theoretic foundation of circuit theory and impedance. Lossless transmission lines. *Morgenthaler*

6.05 ***Circuits, Signals, and Systems***
Prereq.: 6.02, *18.05*
Year: U (1, 2, S) 4–0–8

6.053 ***Circuits, Signals, and Systems***
Prereq.: 6.023, *18.05*
Year: U (1, 2) 4–0–8

Basic subject for students majoring in electrical engineering. Terminal behavior of linear circuits and systems. Impulse response, convolution, and superposition integrals. Complex frequency and system function. Fourier series and Fourier-Laplace integral representations for signals. Feedback systems and stability. Introduction to random signals and noise, correlation functions and spectra, modulation, and detection. *Siebert*

6.06 ***Fields, Forces, and Motion***
Prereq.: 6.03
Year: U (1, 2, S) 3–0–9

6.063 ***Fields, Forces, and Motion***
Prereq.: 6.033
Year: U (1, 2) 3–0–9

Basic subject dealing with 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 elastic bodies and incompressible and compressible fluids. *Melcher*

6.07 ***Energy Transmission and Radiation***
Prereq.: 6.03, 18.05
Year: U (1, 2, S) 4–0–8

6.073 ***Energy Transmission and Radiation***
Prereq.: 6.033, 18.05
Year: U (1, 2) 4–0–8

Basic subject in electrodynamics: wave propagation in one-, two-, and three-space dimensions with emphasis on time-space and frequency-wave-number descriptions. Uniform and non-uniform plane waves; closed and open waveguide structures; energy and energy flow; transmission lines and transmission-line resonators; potentials and Green's function for electromagnetic fields; radiation of dipole antennas and simple arrays; interference and coherence characteristics. *Briggs*

6.08 ***Statistical Mechanics and Thermodynamics***
Prereq.: 8.04
Year: U (1, 2, S) 4–0–8

6.083 ***Statistical Mechanics and Thermodynamics***
Prereq.: 8.04
Year: U (1, 2) 4–0–8

Introductory statistical mechanics: phase space, microcanonical ensembles, the postulate of equal a priori probabilities. Temperature and entropy. The laws of thermodynamics developed from statistical mechanics: work, heat, generalized forces, machines, Legendre transformations and Maxwell relations. Canonical and grand canonical ensembles, partition functions, and the relationship between entropy and information. Quantum systems: Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann statistics. Considerable attention to the derivation of macroscopic properties from microscopic models: ideal, electron and photon gases, dipole systems, and semiconductors. *Crawford*

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 Program 2. 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 under guidance of a staff member. *Eden*

6.13 ***Electric and Magnetic Properties of Matter***
Prereq.: 6.03, 8.04
Year: U (2) 4–0–8

Discussion of electric and magnetic properties of matter using suitable microscopic models with particular emphasis on solids. Electrical conductivity of metals, semiconductors, and insulators. Diamagnetism, paramagnetism, and ferromagnetism. Electronic and ionic contributions to the dielectric constant. Some elements of statistical mechanics and thermodynamics. (*Not offered 1968–69.*) *D. J. Epstein*

6.14 ***Electronic Networks and Devices***
Prereq.: 8.03T
Year: U (1, 2, S) 4–2–6

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. Laboratory. *Staff*

6.17 ***Illumination***
Prereq.: 8.03T
Year: U (2) 3–0–6

Study of visible, ultraviolet, and infrared radiation: characteristics of radiation sources, methods of calculating light and interflections, color specification, design of lighting systems. Useful to anyone interested in light and radiation and applications to lamps, photocells, photometry, radiant heating, bactericidal effect, building illumination, and radiation problems of space flight. (*Not offered 1968–69.*) *Moon*

6.20T ***Electronics in Instrumentation***
Prereq.: 6.05
Year: U (1, 2) 3–0–6

Analysis and design principles of electronic systems for measurement, instrumentation and control. Review of basic devices, circuits, and concepts employed in electronic instrumentation, including analog and digital electronics. Functional elements such as d-c, a-c, and operational amplifiers; regulators; modulators; demodulators; wave and pulse generators, shapers, and detectors; analog and digital gates; basic logic elements. Emphasis on feedback operational amplifiers in instrumentation. *T. S. Gray*

6.202 ***Electronic Light Measurements***
Prereq.: 6.02
Year: U (1, 2) 2–2–5

Principles of the use of light and radiation in pulse form for photography, measurement, and energy conversion. Study and use of instruments for the evaluation of pulsed

(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.

light sources for spectral content, efficiency, and pulse duration. Theory of electronic flash lamps and their application to stroboscopes, photographic light sources, laser stimulators, and instrumentation devices. Use of flash photography to identify and determine position, velocity, and acceleration of objects in space. Frequent laboratory and demonstration experiments to illustrate application of techniques to engineering and scientific measurements. (*For the project laboratory version of this subject see 6.714.*) *Edgerton*

6.213T *Dynamic Systems, Control and Optimization*
Prereq.: 6.05, 18.05
Year: U (1) 3–2–7

6.214T *Dynamic Systems, Control and Optimization*
Prereq.: 6.213T
Year: U (2) 3–2–7

A two-term elective sequence aimed at introducing the main ideas of modern system theory and its applications. Emphasis on problem formulation and synthesis methods. Modeling of systems and signals. State-space description of linear systems. Classical control system design. Quadratic performance criteria and optimal control. Filtering. Stability theory. Static optimization. Dynamic programming. The maximum principle. Laboratory and computer studies.
L. A. Gould

6.215T *Feedback Control Laboratory*
Prereq.: 6.213T
Year: U (1, 2) *Arr.*

Supervised investigation of special projects in feedback control system analysis and synthesis; laboratory investigations utilizing the facilities of the feedback control laboratory. Program and hours to be arranged with interested staff member, subject to approval of instructor.
L. A. Gould

6.216 *Dynamics of Electric Machines* (A, except for Course VI)
Prereq.: 2.02 or 6.01 or 6.48J
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*

6.231 *Programming Linguistics*
Prereq.: 6.47
Year: U (1, 2) 3–2–7

Study of linguistic constructs for the specification of algorithms, and practice in using them to build large semantic structures out of small ones. Initial introduction to and familiarization with a particular general purpose language implemented on a time-sharing system; detailed analysis of the language and its relation to mathematical logic. Bound and free variables, substitution rules, recursion, structures, generalized jumps and labels; contrast and comparison with certain linguistic features of LISP, FORTRAN, ALGOL, PL/I. An introductory subject intended primarily for students whose major interest is computer science. Note: acceptable ability to program a computer will satisfy the 6.47 prerequisite. (*Limited enrollment.*) *A. Evans, Wozencraft*

6.232 *Computational Structures*
Prereq.: 6.002, 6.231
Year: U (1, 2)

Study of hardware and software means for implementing program linguistic features. Theory and design of sequential logic circuits; register transfer operations and logical design; implementation of arithmetic operations; practical memory systems and abstract memory models. Computation schemata accommodating parallelism. Monosequence and multiprocessor implementation; code generation and optimization; process synchronization and determinism. Sharing and nesting of procedures; stacks and recursion. Iteration, qualification and natural parallelism. Information structures, dynamic storage allocation and free storage management. Programming generality and location independent addressing. *Dennis*

6.233 *Information Systems*
Prereq.: 6.232
Year: U (2) 3–0–9

Sources of complexity in information systems, with particular emphasis on problems arising when a single information system serves a community of users. Contrast of problems intrinsic to purposes of use with those related to technical limitations. Study of specific design objectives such as reliability, maintainability, information storage, controlled information sharing, ability to withstand change, and ease of administration. Effect of these and other design objectives on system implementation demonstrated in a model system. Comparison and contrast of model system with current state-of-the-art working systems, including both general purpose community computing facilities and information systems dedicated to a special task such as telephone line switching or air traffic control. *R. M. Graham, Saltzer*

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. May discuss economic, legal, and other non-technical aspects, as well as technical engineering. Faculty counselors to be consulted about availability, field, and instructor. *Adler*

6.243 *Inventions and Patents*
Prereq.: 14.01, 21.012
Year: U (1) 3–0–6

History of private and public rights in scientific discoveries and applied engineering leading to the development of worldwide patent systems. The classes of invention protectable under the patent laws of the United States, including the procedures in protecting inventions in the Patent Office and in the courts. Review of past cases involving various electrical and electronic and other inventions, including the Bell Telephone cases and key radio, solid-state, and computer inventions. *Rines*

6.25T *Digital System Application*
Prereq.: 6.47
Year: U (1, 2) 3–1–8

Introduction to the use of digital computers as engineering tools of analysis as well as on-line laboratory experimental work. Study of the internal structure of digital machines and the hardware-programming tradeoffs conducted through programming exercises in assembly language and logical exercises in combinational and sequential circuits. Elements of digital system design. Case studies of digital information processing systems in which general purpose digital computers and special purpose devices are combined for the solution of complex engineering problems. *F. F. Lee*

6.251 *Digital Computer Programming Systems*
Prereq.: 6.25T or 6.47
Year: U (1, 2) 3–2–7

Basic principles of programming systems. Techniques for translation from problem-oriented languages to machine languages. Computer organization, program-

ming, program planning and organization. Construction of assemblers, interpreters, compilers, monitor, multiprocessed, multiprogrammed systems. The use and manipulation of data structures. Laboratory work in the preparation and testing of programs for the IBM 360 computer. Note: acceptable ability to program a computer will satisfy 6.47 or 6.25 prerequisite.
Donovan, Graham

6.253 *Theoretical Models for Computation*
Prereq : 6.47
Year: U (1, 2) 3–0–9
Study of the theoretical models with widest application to computer logic and programming, stressing equivalence between abstract machines and corresponding formal grammars. Specific topics include: Formal languages and grammars. Operations on sets of sentences. Finite-state machines. State diagrams and linear grammars. Regular expressions. Kleene's theorem on regular expressions and finite-state accepters. Limitations of the finite-state model. Counting and push-down automata. Context-free languages. Ambiguity. Recognition procedures. Turing machines. Elementary theory of recursive functions. Unsolvable decision problems with applications to formal linguistics. *Dennis*

6.256 *Applications of Combinatorial Mathematics*
Prereq.: 6.261 or 18.05
Year: U (2) 3–0–9
Topics in combinatorial mathematics that find frequent application in electrical engineering. Discussion of enumeration techniques will include: permutations and combinations, generating functions, recurrence relations, the principle of inclusion and exclusion, Polya's theory of counting, and permutations with restricted positions. Graph theory and its applications to be covered: planar and dual graphs, chromatic numbers, coefficients of internal and external stability, network flow, and the theory of matching. Other topics to be discussed: linear programming, block design, and projective geometry. *Liu*

6.257 *Switching and Finite Automata Theory*
Prereq.. 6.232 or 6.271
Year: U (1, 2) 3–0–9
Basic properties of Boolean functions, prime implicants the covering problem. Symmetric functions, their detection and implementation. Functional decompositions. Unate and linearly separable functions and their applications to threshold logic. Cellular logic, synthesis and applications. Diagnosis of combinational switching circuits. Redundancies in logical design and improvements in the reliability. The finite state model. State and machine identification experiments. Memory span and information losslessness of finite-state machines. Linear machines, properties and identification, minimization and synthesis, applications to error detection and correction. *Kohavi*

6.261 *Algebraic Foundations for Computer Science*
Prereq.: 6.002 or 18.034
Year: U (1) 4–0–8
Introduction to modern algebra for students interested in computer and information sciences. Emphasis on finite algebraic systems and their applications. Fundamentals of set theory. Natural numbers and induction. Elementary notions of cardinality. General features of algebraic systems: subsystems, isomorphism, homomorphism, quotient systems. Boolean algebras and propositional calculus, with application to logical design. Basic properties of groups. Fields as generalized arithmetic systems. Polynomial rings, congruences, and the construction of Galois fields. *Liu, Hennie*

6.262J *Computability, Formal Systems, and Logic*
(Same subject as 18.165J)
Prereq.: 6.261 or 18.25
Year: U (2) 4–0–8
Study of the basic concepts underlying mathematical theories of computation, with applications to automata theory, programming, and theorem proving. General purpose algorithm schemes and their properties. Recursive derivation, Turing machines and idealized computers. Universal algorithms and the design of universal machines. Computable and non-computable functions. Semantic and syntactic properties of formal systems. The undecidability of various syntactic problems, such as Post's correspondence problem and the tag problem. Logical systems, models, and valuation. Godel's completeness and incompleteness theorems and their implications. *Hennie, Blum*

6.271 *Introduction to Digital Systems I*
Prereq.: 6.001 or *6.01*
Year: U (1, 2) 3–3–6
Introduction to characteristics, specification, and design of digital systems. Boolean algebra, combinational logic, NAND — NOR synthesis and iterative arrays. Elementary properties of finite-state machines. Analysis and synthesis of sequential circuits with pulse and level inputs. Design examples including arithmetic elements, counters and shift registers. Related laboratory treats integrated circuits, static and dynamic properties of gates and flip-flops, synthesis of small digital systems.
Spann, Troxel

6.272 *Digital Systems Project Laboratory*
Prereq.: 6.271, 6.70
Year: U (1, 2) 2–8–2
Introduction to some of the basic techniques used in the design of digital computing and control systems. Preliminary work by a combination of classes, homework, and associated laboratory experiments. Detailed study of comparators, operational amplifiers, analog-digital interfaces, memory systems, and the transmission of digital signals. Implementation of all projects with integrated circuits. Oral presentation and written report on completion of project. Different treatment of material in initial classroom portion from that in 6.711 with accordingly higher standards in the character and scope of projects. (*Credit will not be given for both 6.272 and 6.711.*) *Spann, Troxel*

6.273 *Introduction to Digital Systems II*
Prereq.: 6.232 or 6.271; 6.47
Year: U (1, 2) 3–3–6
Introduction to the structure of modern digital computers. Assembly language programming. Interaction and tradeoff between hardware, programming and processing time. Input-output and interrupt systems. Assemblers and loaders. Formal syntax and semantics of higher level languages. Compilers. Data structures and list processing languages. Laboratory exercises centering around on-line computer usage. (*Not offered 1968–69.*) *F. F. Lee*

6.28 *Probabilistic Systems Analysis*
Prereq.: 18.02
Year: U (1, 2) 4–0–8
Serves as a self-contained development of the theory and application of probabilistic concepts and provides the foundation for graduate subjects in engineering, management, and science. Presentation of the theory of probability on an axiomatic basis. Emphasis on sample

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space concept. Discussion of algebra of events, operations on random variables, discrete and continuous transform techniques, common distributions and stochastic processes, limit theorems, classical and Bayesian statistics. Consideration of implications of probability theory for decision making, data analysis, and system modeling. Presentation of applications concurrently with the development of the theory. *Drake*

6.341 *Principles of Transistors*
Prereq.: 6.02
Year: U (1) 3–3–6
Analysis and design of transistor circuits, based directly on the semiconductor physics and transistor circuit models developed in 6.02. The Photo-diode. Variations of hybrid pi model parameters with current, voltage and temperature. Base resistance. Single-stage and multistage linear circuits. Physics, models, and circuit applications of field-effect transistors. High-frequency and low-frequency response calculations of transistor and FET circuits using a computer. The charge-control model. Computer-aided analysis of switching transients. Regenerative switching circuits. *Searle*

6.343 *Computer-Aided Circuit Design*
Prereq.: 6.341, 6.47
Year: U (2) 3–0–9
A supplement to 6.341 with particular emphasis on the use of computers in the analysis and simulation of electronic circuits. Computer models for semiconductor circuits; difference equation formulation of circuit problems; numerical methods for iteration, integration, and optimization; matrix representation of circuits and numerical methods for manipulating matrices; time and frequency-domain calculations. (*Permission of instructor required.*) *Thornton*

6.35 *Acoustics*
Prereq.: 6.01, 18.05
Year: U (1) 3–1–6
General discussion of sound generation and propagation in elastic media. Conversion between acoustical, electrical, and mechanical energy. Lumped-parameter approximations. Sound in rooms, microphones, loudspeakers, and audio communications systems; noise and vibration control problems. Interaction of sound and man. *Stevens*

6.36T *Sound, Speech and Hearing*
Prereq.: 6.03, 6.05
Year: U (1) 3–0–9
Introduction to the physical, physiological and psychological bases of speech production and reception. Physical acoustics, properties of neural and muscular elements, respiration, the vocal tract and speech generation, signal transmission in the auditory system, perception of attributes of speech and speechlike sounds, and the linguistic units that underlie speech events.
Klatt, Peake, Stevens, T. F. Weiss

6.37 *Sensory Communication*
Prereq.: 6.05
Year: U (1) 3–3–6
Examination of human sensory performance from the viewpoint of the communication sciences. Information flow diagram of a model sensory system. Introductory discussion of the behavior of transducers and neurons in such systems. Input-output relations derived from responses of the organism to auditory, visual, and other sensory stimuli. Psychophysical methods for the measurement of sensory capacities including absolute and differential sensitivity, span of absolute judgment, operating characteristics of human observers, reaction times, confusion matrices, etc. Laboratory experiments illustrating these methods. Models relevant to these data: detection theory, the psychophysical law, channel capacity, information processing in the human observer viewed as a single channel. Psychophysical data and models in relation to sensory performance in natural communication tasks. *Rosenblith*

6.372 *Biophysics of Neuroelectric Potentials*
Prereq.: 6.01 or 6.14; 8.03T; 18.034
Year: U (2) 3–3–6
Introduction to basic phenomena of generation, transmission and interaction of signals in nervous systems. Discussion of the excitation and conduction of the nerve impulse along nerve fibers, synaptic transmission and transduction processes in receptors. Use of mathematical models — particularly electric circuit models — in describing the behavior of cell membranes. Laboratory experiments illustrating the relations between theoretical formulations and experimental data in this field and introducing some techniques of recording electric activity from nerve tissue. *Peake, Weiss*

6.39 *Image Transmission Systems*
Prereq.: 6.05
Year: U (1) 3–0–6
Efficient design of Image Transmission Systems, which differ from other information systems both in the multidimensional nature of the inputs and the destination of the output, and therefore depend on a study of the properties of pictures, the properties of observers, and the effect of the parameters of the system on the quality of the transmission. Topics including historical developments, mathematical description of images, objective measures of picture quality, scanning and quantizing, picture processing and coding, color systems, and relevant properties of human vision. Term paper or project required. *Schreiber*

6.47 *Introduction to Automatic Computation*
Prereq.: ——
Year: U (1, 2) 2–2–2
Modeling of computational processes as sequential algorithms. Formal and informal techniques for the representation of these algorithms and their implementation on digital computers. Experience in programming and running of elementary problems in an algebraic and an assembler language. *Anger*

6.471 *Introduction to Automatic Computation*
Prereq.: ——
Year: U (1, 2) 1–0–5
Experimental version of 6.47. Direct communication between students and a large-scale digital computer. (*Registration limited. Permission of instructor required.*)
Weizenbaum, Fenichel

6.48J *Electromechanical Fields and Systems*
(Same subject as 2.13J)
Prereq.: 2.02 or 6.01
Year: U (1, 2) 4–2–6
Elementary treatment of fields in vacuum and real materials with emphasis on energy principles and force relationships. Emphasis on quasi-static electromagnetic fields through application of Maxwell's equations with brief discussion of gravitational, thermal and fluid fields. Relation between field and lumped circuit concepts. Multiport energy transformers and transducers. Practical applications to design and utilization of electromechanical devices and systems, including measuring instruments, control components, and rotating machines. Design and laboratory work illustrating practical and theoretical questions. *Kingsley, Paynter*

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. *Searle*

6.512 *Development of Inventions and Creative Ideas* (A)
Prereq.: 14.01, 21.02
Year: G (2) 3–0–9
The role of the engineer as patent expert and as technical witness in court and patent interference and related proceedings, with emphasis on actual experiences in the field of electrical and electronic engineering. Rights and obligations of engineers in connection with various types of employment contracts and employers, including educational institutions, government, and large and small businesses. Various manners of transplanting inventions into business operations, including the development of the New England electronics industry and its different types of institutions. American systems of incentive to creativity apart from the patent laws, including provisions relating to inventions and ideas in the atomic energy and space fields. (*For graduate students only; others see 6.243.*) *Rines*

6.527 *Continuum Electromechanics* (A)
Prereq.: 6.06
Year: G (2) 3–0–9
Dynamics of continuous media in electric and magnetic fields with emphasis on electrohydrodynamics and magnetohydrodynamics. Relaxation and diffusion phenomena in the presence of material motion. Continuum conduction, induction, and synchronous interactions in electric and magnetic field systems. Electromechanical dynamics in terms of waves and instabilities. Field-coupled forms of Rayleigh-Taylor and Kelvin-Helmholtz instability. Traveling wave energy conversion schemes, growing waves and non-linear wave phenomena. Integral conditions and variational methods in the study of instability. Introduction to the continuum feedback control of electromechanical systems. *Melcher*

6.535 *Structure of Computing Systems* (A)
Prereq.: 6.25T or 6.251
Year: G (2) 3–0–9
Study of the design of general purpose digital computing systems in relation to programming languages used to specify procedures, the design of compilers, the devices and technology employed in fabrication, interaction between procedures and system environment, and the efficient utilization of resources. Trends in contemporary computer system design. Basic properties of procedures and their representation. Syntax and semantics of programming languages. Translation into an intermediate procedure language. Languages for describing the structure of digital machines. Example of subsystem designs. Realization of arithmetic operations. Associative and pseudo-associative memories. The problems of multiprogrammed computer system design. Modular organization of hardware. The necessity for address transformation and its implementation. Models of program structure. Parallel programming. Allocation and scheduling techniques. *Dennis*

6.536 *Probabilistic Models in Systems Engineering and Operations Research* (A)
Prereq.: 1.07 or 6.28 or 18.10 or 18.18; 15.092 or 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 non-stationary, Markov and semi-Markov processes. Optimization of probabilistic systems over short and long time periods by means of dynamic programming. Concurrent presentation of examples in the areas of system reliability, congestion processes, automatic control, maintenance and replacement policies, search procedures, inventory control, and other operating problems of systems. Discussion of unsolved problems and promising areas of research. *Drake*

6.537 *Computational Models* (A)
Prereq.: 6.271
Year: G (1) 3–0–9
Basic properties and capabilities of finite-state machines. Graphical descriptions of machine behavior. Experiments for determining internal state or detecting malfunctions. Decomposition of machines into combinations of submachines. Regular expression descriptions of machine behavior. Analysis of systems with bi-directional information flow, including information lossless machines, iterative arrays, and coding schemes. Two-dimensional computations, including circuits for performing arithmetic operations. Space-time transformations and synchronization problems. *Hennie*

6.538 *Computational Models* (A)
Prereq.: 6.537
Year: G (2) 3–0–9
Study of basic ways of formulating computational problems, including machine models, functional models, and linguistic models. Comparison of these models and their properties, leading to an understanding of computability and decidability. Topics included: non-writing automata, push-down store automata, and Turing machines; computers and their relationship to Turing machines; recursive function theory; rewriting algorithms and context-free languages. *Hennie*

6.539 *Mathematical Theory of Computation and Symbol Manipulation* (A)
Prereq.: ——
Year: G (1) 3–0–9
Theory of representing effective processes — recursive functions — a way that clarifies the relation between classical logical systems and processes described by computer programs. LISP programming language; LISP as a metalanguage for first-order logic. Computability and unsolvability. Godel's incompleteness theorem. Processes for proving theorems, searching trees, and performing syntactic analysis. This subject and 6.544J (18.16J) recommended as a two-term introduction to artificial intelligence. *Minsky, Moses*

6.541 *Special Topics in the Computer Sciences* (A)
Prereq.: ——
Year: G (1) *Arr.*

6.542 *Special Topics in the Computer Sciences* (A)
Prereq.: ——
Year: G (2) *Arr.*
A seminar-type discussion of special topics in the computer sciences. Opportunity for graduate students and instructors to investigate a topic of common interest. Topic and staff announced each term. These subjects given independently or sequentially, as circumstances require. (*Consent of instructor required.*) *Fano*

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6.544J *Heuristic Programming and Artificial Intelligence* (A)
(Same subject as 18.16J)
Prereq.: ——
Year: G (2) 3–0–9
The problem of making machines behave intelligently. Application of machines to problems of learning, induction, pattern-recognition, game-playing, theorem-proving, neural nets, self-organizing systems, and other areas where problems have been solved by heuristic programming. Problems in administration and allocation of effort within programs. Models of cognitive processes. Machine aids for human problem solving. (*Ability to program a computer required.*) *Minsky, Papert*

6.551 *Power System Engineering I* (A)
Prereq.: 2.03 or 6.06; 2.062 or 6.07
Year: G (1) 3–0–9
Primarily for first-year graduate students. Introduction to power system engineering. Definition of an electric power system in terms of its principal functions and major components. Modeling of the following components — generating units, transformers, transmission lines, and circuit breakers using the concepts and techniques of field theory, circuit theory, etc. Use of these models to study those problems in which electrical behavior is quasi-steady-state, for example, load flow, overvoltage conditions, fault currents, and transient stability.
Woodson, G. L. Wilson

6.552 *Power System Engineering II* (A)
Prereq.: 6.551
Year: G (2) 3–0–9
Continuation of 6.551, Power System Engineering I. Refinement of component models to represent transient electrical phenomena such as switching surges and lightning impulses; surge control and protection; control systems for generators, turbines, and synchronous condensers; effect of excitation on system stability; corona and radio interference from transmission lines; direct current transmission. *Woodson, G. L. Wilson*

6.553 *Special Topics in Power System Engineering* (A)
Prereq.: 6.552
Year: G (2) 3–0–9
Treatment in depth of special topics in power system technology by notable experts in the field.
Woodson, G. L. Wilson

6.56 *Electronic Circuits* (A)
Prereq.: 6.02, 6.05, 6.47
Year: G (1) 3–0–9
Theory and analysis of non-linear and active circuits with particular emphasis on the use of numerical methods. Matrix operations and transformations; realizability conditions; numerical methods for iteration, integration, and optimization; computer simulation in the frequency domain; sensitivity, noise, and tolerance considerations. Extensive use of digital computers. *Thornton*

6.561 *Network Synthesis* (A)
Prereq.: 6.05
Year: G (2) 3–0–9
Introduction to the theory of linear network synthesis. The basic synthesis elements: resistors, capacitors, inductors, transformers, and gyrators. Internal and external description of networks via differential equations, impedances, admittances, and scattering parameters. Passivity and reciprocity. The classical driving-point synthesis procedures of Foster, Cauer, Brune, Darlington, and Bott-Duffin. n-port synthesis procedures based on matrix factorization. Reducing the n-port synthesis problem to a resistive synthesis using reactance extraction.
Brockett

6.568 *Principles of Communication*
Prereq.: 6.05; 6.28 or 18.18
Year: G (1) 3–0–9
Probabilistic formulation of the communications problem. Mathematical description of signals and noise. Decision regions and optimum receivers. Discrete modulation and signal design. Introduction to channel capacity and error-free communication over noisy channels. Performance and limitations of continuous modulation systems (AM, FM, PPM). Interchange of bandwidth and signal-to-noise ratio; threshold effects.
Hoversten

6.569J *Space Communications* (A)
(Same subject as 16.45J)
Prereq.: ——
Year: G (1) 3–0–9
Study involving the important interaction between the orbital and dynamical characteristics of spacecraft, the transmission of electromagnetic signals over long distances and the concepts of modern communication theory. Stress on interplay between these diverse topics in practical space communication systems. Discussions of spacecraft dynamics, stabilization, attitude control, propagation effects and pertinent modulation and coding methods. (*Some background in space dynamics or in communications assumed. Permission of instructor required.*)
Harrington

6.57T *Probability Theory and Linear Systems* (A)
Prereq.: 6.01, 18.05
Year: G (1) 3–0–9
Combination of an elementary introduction to probability theory with a brief review of the methods for the representation and analysis of linear systems. Specifically intended for first-year graduate students who seek to strengthen their preparation for further studies in the area of statistical communication theory. Axiomatic foundations of probability theory, random variables, distributions, expectations, characteristic functions, transformations of variables, and laws of large numbers. Some simple applications to statistics. Linear systems in the time and frequency domains — convolution and Fourier-Laplace integral representations. Examples which illustrate important concepts and problems in modern communication. *Siebert, Van Trees*

6.571 *Statistical Theory of Communication* (A)
Prereq.: 6.05
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 (2) 3–0–9
Operators and functionals. Volterra functional power series representation for non-linear systems. Techniques for the study of non-linear systems under functional representation when the input is a transient, a sinusoid, or a random process. Emphasis given to non-linear systems with random inputs. Representation of non-linear systems by Wiener's orthogonal functionals. Measurement of the kernels of a non-linear system by cross-correlation. Model of a non-linear system in the form of a Laguerre-

Hermite expansion. Synthesis of non-linear systems. The optimum non-linear filter, predictor, and general operator. Use of Bose's gate functions in non-linear problems. Determination of functional representation for a non-linear system from non-linear differential equation representation. Application of functional techniques to modulation problems. *Y. W. Lee*

6.573 *Introduction to Random Processes* (A)
Prereq.: 6.05, 6.28; 6.57T
Year: G (1, 2) 3–0–9
Random processes: partial and complete characterization, stationary and ergodicity. Calculus of random processes: continuity, integration, and differentiation. Functions of random processes. Characterization of linear systems using impulse responses and state-variables. Input-output relations for random processes in linear systems. Differential equations driven by random processes. Process measurements and statistics: mean, distribution function, spectrum, and correlation function. Representation of processes: sampling theorem, orthogonal series, spectral decomposition. Poisson processes. Renewal processes. Gaussian processes. Markov processes: discrete time-continuous state and introduction to continuous time-continuous state. Emphasis on developing an ability to reduce engineering problems to a mathematical model, to solve the resulting probabilistic problem, and to appreciate the significance and limitations of the results. *Van Trees, Hoversten*

6.574 *Transmission of Information* (A)
Prereq.: 6.28 or 6.57T or 6.573 or 18.18
Year: G (1, 2) 3–0–9
Introduction to the quantitative study of communication processes, with emphasis on the concepts fundamental to the engineering of accurate, efficient communication systems. Definition of a measure of information and study of its properties; efficient representation of discrete message sources; communication channels and their capacity; encoding and decoding of data for transmission over noisy channels and evaluation of bounds to the probability of decoding errors. *Gallager*

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. *R. S. Kennedy*

6.576 *Detection, Estimation, and Modulation Theory* (A)
Prereq.: 6.57T and *6.573;* or 6.573
Year: G (1, 2) 3–0–9
A unified approach to the areas of detection, estimation, and modulation theory. Classical detection and estimation theory: Bayes, Neyman-Pearson tests; Bayes estimation, Maximum likelihood estimation. Process representations. Detection of signals in Gaussian noise. Fredholm integral equation theory. Signals with unwanted parameters, composite hypotheses. Estimation of continuous waveforms. Linear estimation. Wiener filters. Closed-form error expressions. Differential equation representation of linear systems. Kalman-Bucy filters. Non-linear modulation theory: phase-lock loops, optimum angle modulation, rate distortion theory. Comparison of various communication systems. Gaussian signals in Gaussian noise: detection and parameter estimation. *Van Trees*

6.577 *Modulation Theory and Systems* (A)
Prereq: 6.573, 6.574
Year: G (2) 3–0–9
Application of information and detection theory to important waveform communication systems such as additive noise channels, filtered channels, and fading dispersive channels. Determination of the fundamental performance limitations of channels and of the signaling systems which approach these limits. The design, instrumentation, and evaluation of systems employing digital and analog techniques. Coder and decoder implementation and characteristics. Time, frequency, and coding diversity. Tracking and equalization of time-varying channels. Performance of continuous modulation systems; noise suppression; thresholds and their relationship to channel capacity. *R. S. Kennedy*

6.578 *Advanced Topics in Random Processes* (A)
Prereq.: 6.573
Year: G (2) 3–0–9
Additional study of the theory of random processes introduced in 6.573. Topics change from year to year at the discretion of the instructor in charge.
Van Trees, Snyder

6.579 *Probability Theory and Random Processes* (A)
Prereq.: 18.034 or 18.07
Year: G (1) 3–0–9
An introduction to the theory of probability and random processes with engineering applications. Probability as a model for empirical averages. Random variables and probability distribution functions. Statistical averages. Elements of estimation and sampling theory. Correlation and characteristic functions. Basic properties of the simple random walk, Markov chains, and the Poisson and Gaussian random processes. Passage of random processes through linear systems, definition of spectra, and an introduction to the theory of optimum linear systems. Various additional applications at the discretion of the instructor. *(Restricted to Practicing Engineers in the Center for Advanced Engineering Study.)*
Davenport

6.58 *Electrodynamics of Waves, Media, and Interactions* (A)
Prereq.: 6.06; 6.07 or 6.584
Year: G (1) 3–0–9
Intended for first-year graduate students whose major interest is in the interaction of electric and magnetic fields with charged particles and continuous media. Radiation and Cherenkov fields from moving charges. Wave propagation in continuous media and their dispersion relations; energy and energy flow associated with wave propagation in passive and active media. Coupling of modes in stable and unstable systems; general stability criteria and techniques for identifying and classifying wave-type instabilities. Examples are taken from plasma, magnetostatic, acoustic, electromechanical and electron-beam waves and interactions. *Bers*

6.583 *Advanced Topics in Continuum Electrodynamics* (A)
Prereq.: 6.03 or 6.584 or 8.311T
Year: G (1) 3–0–9
Precise material to be covered and prerequisites to differ from year to year according to interest of the instructor in charge. Typical subjects: electromagnetism of moving media, continuum electrohydrodynamics, antennas and propagation, waves in dispersive media. In 1968-69: fundamental macroscopic equations of electrodynamics of moving media, and the force of electromagnetic origin in polarized and magnetized bodies. Principle of virtual power and energy-momentum tensors, both non-relativistic and relativistic. Equivalence of various formulations of electrodynamics, especially the two models for magnetization. *Penfield*

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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.: 18.034
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. (*Not offered 1968–69.*) *Moon*

6.59 *Bioelectric Signals* (A)
Prereq.: ——
Year: G (2) 3–0–9
For graduate students in the communication sciences. Neuroelectric activity in relation to sensory information processing. Firing patterns in single neurons and evoked responses in different biological species including man. Effect of the state of an organism upon the observable neuroelectric activity. Time-locked events in the central nervous system. Kinds of constraints which knowledge of neuroelectric activity imposes upon model making or simulation in relation to sensory performance. (*Admission only by permission of instructor.*) *Rosenblith*

6.591 *Signal Transmission and Coding in the Auditory System* (A)
Prereq.: 6.03, 6.05, 6.28, 6.372
Year: G (1) 3–0–9
Intended for graduate students with a serious interest in sensory physiology. Discussion centering on responses of the auditory system to acoustic stimuli. Presentation aimed at understanding of the physiological mechanisms involved in the transmission and processing of signals and transformations. When possible, consideration of the relations of physiological signals to psychophysical measurements. Major emphasis on the more peripheral parts of the system: diffraction of sound by the head; signal transmission in the external ear, middle ear, cochlea, auditory nerve, cochlear nucleus, superior olivary complex. Some discussion of the anatomy and physiology of higher levels. (*Alternate years. Appropriate background other than the listed prerequisites may be accepted by the instructor.*) *Kiang, Peake, T. F. Weiss*

6.592 *Analytical Models for Human Processing of Sensory Inputs* (A)
Prereq.: 6.37 or 6.372
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. (*Not offered 1968–69.*) *Eden*

6.594 *Cognitive Information Processes* (A)
Prereq.: 6.25T or 6.592
Year: G (2) 3–0–9
Discussion of research and theory pertaining to the description of the higher mental processes. Perception, memory, and language regarded as information systems and the cognitive processes involved in their operation and in communication between them. Coding of the environment, perception of space and time, linguistic control of perception. Extensive readings in the literature. (*Not offered 1968–69.*) *Kolers*

6.595 *Communication Sciences Seminar* (A)
Prereq.: 6.05
Year: G (1) 3–0–9

6.596 *Communication Sciences Seminar* (A)
Prereq.: 6.05
Year: G (2) 3–0–9
Selected topics relevant to research areas in which the theory and techniques of communications, information, and control engineering bear upon problems in the life sciences. Intended mainly for electrical engineering graduate students interested in communications science, but also open to students in fields such as linguistics, psychology, and physiology. Reading, discussion, and the preparation of individual term papers. Material varying from term to term and year to year.
Eden, S. J. Mason

6.60 *Analysis of Dynamical Systems* (A)
Prereq.: 6.05
Year: G (1, 2) 3–0–9
An integrated and rigorous approach to the analysis of forced and unforced dynamical systems from both a state space and operator theoretic point of view. Preparatory for advanced study in control theory. Discussion of matrices, their properties, and more general linear transformations. Basic existence and uniqueness theorems for differential equations, linearization of non-linear differential equations about an equilibrium point and about a nominal trajectory, numerical solution of differential equations. Linear constant systems and their solution in the time and frequency domain. Linear time-varying systems and their solution in terms of the transition matrix. Properties of dynamical systems including controllability, output controllability, normality, observability, and the interpretation of these properties for linear systems. The stability of dynamical systems including the Routh-Hurwitz, Nyquist, circle, and Popov criteria. Introduction to quadratic optimization of linear systems in both the time and frequency domain. *Brockett*

6.601 *Control System Theory* (A)
Prereq.: 6.05; *6.57T* or *6.571* or *6.573*
Year: G (1) 3–0–9
Introduction to basic theory for analysis and design of control systems. Emphasis on linear, infinite time interval problems. Mathematical models for dynamic systems. Review of transforms and stability criteria. Analyses for transient and steady-state response. Root loci. Trial-and-error design techniques using frequency response methods. Optimization theory for stochastic and deterministic signals. Selected topics from: sampled-data theory, analytical tools for stability of non-linear systems, simulation and computation techniques, sensitivity analysis, and control system components. (*For graduate students without prior background in control.*) *Newton*

6.602 *Nonlinear Dynamical Systems* (A)
Prereq.: 6.60
Year: G (2) 3–0–9
Introduction to basic non-linear phenomena using linearization and the method of averaging. Stability concepts. Use of Liapunov functions and contraction arguments in establishing stability criteria. Passivity in linear and non-linear systems. Study of time-varying and non-linear feedback loops including free and forced responses, jump phenomena, and subharmonic generation. Use of path integrals to determine frequency domain stability criteria. Applications drawn from mechanics, electronics, and automatic control. *Brockett*

6.603 *Seminar in Control Research* (A)
Prereq.: 6.213T or 6.601
Year: G (1, 2) 3–0–9
Further preparation for graduate research in the control field. Topics, such as non-linear theory, optimal control, and stability theory, e.g., selected according to student and staff interests. Reading and discussions supervised by one or more staff members and specialists. Specific topics and arrangements announced each term. Consent of instructor required. *Newton*

6.604J *Special Studies in Systems Engineering* (A)
(Same subject as 1.16J, 2.191J, 13.47J)
Prereq.: 6.536 or 6.571 or 6.573 or 6.601 or 6.632
Year: G (2) 2–4–6
Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — integrated urban transportation system. Group 2 — manned satellite inspection and retrieval system.) *Seifert, de Neufville, Baumann, Frankel*

6.605 *Simulation Methods for Analysis and Control* (A)
Prereq.: 6.213T or 6.601
Year: G (2) 3–0–9
Introduction to simulation methods for analysis of complex dynamical systems and their controls. Assumption of background of elementary control theory. Some knowledge of digital computer programming an asset. Treatment of analog, hybrid, and digital methods for simulation by means of case studies. Use of one or more special languages useful in digital simulations. Speed and cost of alternative computing procedures. Emphasis on analytical checking methods and pertinent questions of numerical analysis. Illustration of modern simulation methods by project-type problems using both analog and digital facilities. *Newton*

6.606 *Stochastic Dynamic Systems* (A)
Prereq.: 6.28 or 6.57T or 6.573 or 18.18; 6.60
Year: G (2) 3–0–9
State space approach to dynamic systems with uncertainties. Emphasis on stochastic models with consideration of non-probabilistic models for uncertainty. Linear, non-linear, discrete time and continuous time models and analysis suitable for computer solution. Estimation methods such as: Bayesian, Fisher, Kalman-Bucy, weighted least squares, unknown but bounded. Gaussian and minimum residual decision theory, distance measures. Introductions to: measurement design, system identification, adaptive systems, stochastic approximation, stochastic control. *Schweppe*

6.607 *Special Problems in Control* (A)
Prereq.: 6.05 or 6.213T or 6.601
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.: 6.60 or 6.601 or 10.35
Year: G (2) 3–0–9
Control of industrial processes with emphasis on applications in the chemical industries. Development of lumped and distributed models of processing units. Partial differential equations of linear convective processes and approximate methods of solution. Conventional regulation theory; cascade, feedforward, and non-interacting control. Modal analysis and state space representation of lumped and distributed systems; modal control. Introduction to optimal control of chemical reactors and distributed systems. *L. A. Gould*

6.609 *Theory of Optimal Control* (A)
Prereq.: 6.60
Year: G (1) 3–0–9
Review of state space representation of dynamical systems. Definition of the optimal control problem. Bounded controls and the sets of reachable states. Necessary and sufficient conditions for optimality; the classical variational approach, the Maximum Principle of Pontryagin, the Hamilton-Jacobi theory. Existence and uniqueness theorems. Applications of the theory to minimum time and minimum fuel problems; the design of time- and fuel-optimal systems using switch curves and switch surfaces. The design of optimal linear regulators and tracking systems with respect to quadratic performance criteria; the matrix Riccati equation approach. Introduction to the Wiener-Kalman-Bucy filter theory. Introduction to computational techniques for the solution of optimization problems. *Athans*

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. (*Not offered 1968–69.*) *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*

6.624 *Detection and Measurement of Radio Astronomical Signals* (A)
Prereq.: 6.07
Year: G (1) 3–0–9
Detection and measurement of radiation typical of signals encountered in radio astronomy. Characterization and measurement of random electromagnetic fields, including their spatial, angul time, and polarization correlation properties. Holograms. Angular filtering properties of antennas, including interferometers and aperture synthesis systems. Antenna temperature and gain. Statistical analysis of signal processors, including basic radiometers, spectrometers, interferometers, and certain digital systems. Noise characterization and analysis for n-port networks. The equations of radiative transfer and their inversion. Applications of parameter estimation theory. (*Not offered 1968–69.*) *Staelin*

(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.

6.625J ***Fundamentals of Radio Astronomy*** **(A)**
(Same subject as 8.951J)
Prereq.: 6.624 or 8.05 or 8.211
Year: G (2) 3–0–9
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, spectral line radiation from H, OH, and other atoms and molecules, 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, physics of the interstellar medium, origin of cosmic rays, cosmology. Radio astronomical observations and experiments from space vehicles. (*No prior knowledge of astronomy or astrophysics required. Students who wish to do thesis work in this area are advised to take 6.624 and 6.625J.*) *Staelin, Barrett*

6.631 ***Plasma Dynamics*** **(A)**
Prereq.: 6.58
Year: G (2) 3–0–9
Introductory subject in plasma phenomena. Motion of charged particles in electric and magnetic fields; adiabatic invariants; drifts due to magnetic field gradients. Collision theory. The Boltzmann equation and derivation of the macroscopic transport equations. Plasma waves such as electromagnetic waves, whistlers, helicon waves, electron and ion acoustic waves. The magnetohydrodynamic limit and Alfvén waves. *Briggs, Parker*

6.632 ***Electronic Instrumentation and Control*** **(A)**
Prereq.: 6.05
Year: G (1) 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*

6.635 ***Semiconductor Electronics*** **(A)**
Prereq.: 6.08, 6.341
Year: G (1) 3–0–9
Principles and applications of some of the electronic properties of semiconductors important for devices: Use of quasi-fermi levels in the description of p-n junctions and transistors; review of diode and transistor performance at high injection levels; statistics of recombination and trapping, and effect on diode and transistor characteristics; avalanche processes in p-n junctions and transistors; four-layer diodes and controlled rectifiers; field effect transistors. *R. B. Adler*

6.636 ***Microelectronics*** **(A)**
Prereq.: 6.341
Year: G (2) 3–0–9
Principles and applications of microelectronics with particular emphasis on silicon monolithic integrated circuits. Fundamental limitations of microminiaturization. Physics and metallurgy of the technologies used. Physical description of device performance and device design for integrated circuits. Comparison of discrete digital and linear circuits with monolithic versions, emphasizing design constraints imposed by the monolithic technique. Two weeks of laboratory work evaluating and utilizing digital and linear integrated circuits. *Smythe*

6.638 ***Seminar on Solid-State Plasma Effects*** **(A)**
Prereq.: 6.08, *6.58*
Year: G (2) 3–0–9
Intended for students with graduate background in either solid-state or plasma physics. Simple wave phenomena in solids: helicon, Alfvén, optical, and acoustic plasma waves. Emphasis on unifying role of frequency- and wavevector-dependent dielectric tensor as well as the similarities and differences between solid-state and gas plasmas. Treatment of resonant (Landau) and non-resonant damping from both classical and quantum points of view. Discussion of various types of growing waves and instabilities, including acoustic wave amplification, two-stream instabilities, pinching, helical density waves, and the Gunn effect. Use of plasma effects for band structure determination. Application of Landau Fermi-liquid theory to metals and semimetals. (*Not offered 1968–69.*) *McWhorter, Bers*

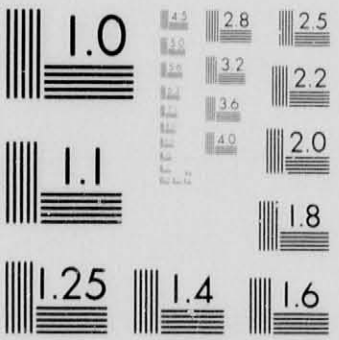
6.639 ***From Atoms Toward Living Systems*** **(A)**
Prereq.: ——
Year: G (2) 3–2–7
An attempt to bridge between the materials sciences and the life sciences. The electronic structures of atoms and the implications of the Periodic System, development of the theme in lectures and round-table discussions from gases to liquids and solids, from insulators to conductors, from the molecular architecture of static systems to the operation principles of dynamic systems and living cells. *von Hippel*

6.64J ***Electronic Materials*** **(A)**
(Same subject as 3.76J)
Prereq.: 3.15; or 6.02 and 6.13; or 6.02 and 6.341
Year: G (2) 2–0–6
Various aspects of electronic materials such as preparation, purification, crystal growth, crystal structure, characterization, electronic properties, band structure and device applications. Special emphasis on relationships between structural characteristics, atomic bonding and physical properties in classes of materials such as elemental and compound semiconductors, thermoelectrics and superconductors. Extensive rather than intensive coverage. *Gatos, Witt*

6.641J ***Laboratory in Physics of Solids*** **(A)**
(Same subject as 3.40J)
Prereq.: 3.15 or 6.08; 8.04 or 8.211
Year: G (1, 2) 0–8–4
Experimental investigations on the physical properties of materials closely related to current research; brief lectures on the basic theories and experimental methods. Experiments in areas of: X-ray diffraction, galvanomagnetic effects, superconductivity, ferroelectricity, crystal growth, infrared absorption, Mössbauer effect, thermal properties, magnetic resonance, dielectric properties, carriers in semiconductors, elastic constants, defect structures. *A. C. Smith, Moss*

6.642 ***Special Topics in the Solid State and Its Application*** **(A)**
Prereq.: 8.321T
Year: G (1) 3–0–9

6.643 ***Special Topics in the Solid State and Its Application*** **(A)**
Prereq.: 8.321T
Year: G (2) 3–0–9
Primarily for those interested in research on solid-state materials and devices for electrical and electronic applications. Topics and staff to be announced each term. Given independently or sequentially as circumstances require. (*Permission of instructor required.*) *R. B. Adler*



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6.644 *Microwave Magnetics* (A)
Prereq.: 6.06 or 6.07; 8.04
Year: G (2) 3–0–9
Introduction to the propagation and mutual interaction of microwave photons, magnons, and phonons in ferro-, antiferro- and ferrimagnetic crystals. Molecular field theory of ferrimagnetism. Quantum mechanical and semi-classical treatments of magnons including dipolar interactions; harmonic oscillator approximation of spin waves and Holstein-Primakoff transformations. Elementary domain theory. Linear and non-linear effects associated with magnetic resonance. Propagation of electromagnetic waves in ferrite-loaded waveguides; reciprocal and non-reciprocal microwave circuit elements such as rotators, isolators and circulators. Magnetoelastic wave propagation in exchange-coupled gyromagnetic media when magnetostriction is present. Detailed study of the electromagnetic, exchange, and elastic channels of power flow. Linear and non-linear mechanisms of magnon/photon and magnon/phonon conversion; applications to fundamental spectroscopy and to the field of microwave devices. *Morgenthaler*

6.645 *Topics in Semiconductor Device Research* (A)
Prereq.: 6.08, 6.341; 6.651J or 8.511T
Year: G (2) 3–0–9
Relationship of the electrical properties and band-structure of semiconductor materials to device performance. Device applications of the following phenomena: tunneling, heterojunctions and Schottky barriers, impurity- and impurity-band-conduction, hot electron effects including the Gunn effect, avalanche including avalanche transit time oscillators, injection luminescence including laser action, photo-detection including light-coupled amplifiers. *Rediker*

6.646 *Conduction Processes in Solids* (A)
Prereq.: 6.08; 6.651J or 8.511T
Year: G (2) 3–0–9
Topics in transport theory, including crystal symmetry, Onsager relations, 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. *A. C. Smith*

6.647 *Electronic Properties of Solids* (A)
Prereq.: 6.651J or 8.511T
Year: G (1) 3–0–9

6.648 *Electronic Properties of Solids* (A)
Prereq.: 6.647 or 8.511T
Year: G (2) 3–0–9
Development of empty lattice, weak binding and tight binding approximations for energy bands, group theory with applications to solid-state problems, symmetry methods for energy band models, spin-orbit coupling. Survey of techniques for energy band calculations. Discussion of effective mass theory, Bloch electron in a magnetic field, deformation potentials. Illustrative discussion of the relationship of the above to transport properties, to optical and magneto-optical properties, and to the study of the Fermi surface. *Pratt*

6.649 *Quantum Electronics* (A)
Prereq.: 6.651J or 8.05
Year: G (2) 3–0–9
Quantum states and energy levels. Time-dependent perturbation theory and relations to line broadening. The density matrix and its time evolution. Quantization of the electromagnetic field. Spontaneous and stimulated emission of radiation. Negative temperatures and population inversion as a driving source of an electromagnetic field. Lamb's theory of optical lasers. Coherence of optical fields, fluctuations, photon statistics and noise. Gas and semiconductor lasers. Electro-optic effects and non-linear optics. *Pratt*

6.65 *Quantum Theory of Magnetism* (A)
Prereq.: 6.651J or 8.511T
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. 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*

6.651J *Physics of Solids* (A)
(Same subject as 3.42J)
Prereq.: 3.41; or 6.03 and 8.05; or 6.03 and 8.211
Year: G (1) 3–1–8
First term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Emphasis on mathematical methods and physical models which have proven to be generally useful in obtaining quantitative descriptions of physical quantities. Student use of a computer console to solve quantitative problems; no programming experience necessary. Topics: diffraction of X rays, electrons, and neutrons by solids; periodic structures and reciprocal space; lattice dynamics, normal modes and phonons; quantum statistics; electron states in solids, Bloch waves and energy bands; perturbation theory; classification of solids. *Kaplow, A. C. Smith*

6.652J *Physics of Solids* (A)
(Same subject as 3.43J)
Prereq.: 3.42J or 6.651J
Year: G (2) 3–1–8
Second term of a two-term sequence presenting the basic concepts of the quantum theory of crystalline materials. Topics: dynamics of electrons in solids, effective mass theorem; transport phenomena, electrical conductivity; magnetic phenomena, angular momentum and spin; paramagnetism, diamagnetism, ferromagnetism; interaction of radiation with solids, optical properties, resonance phenomena. *A. C. Smith, Sellmyer*

6.66 *Engineering Applications of Tensors* (A)
Prereq.: 8.04
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. (*Not offered 1968–69.*) *Moon*

6.681 *Introduction to Electrical Engineering Research* (A)
Prereq.: ——
Year: G (1) *Arr.*
Lectures on research currently under way in Department of Electrical Engineering. 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. (*Restricted to entering graduate students in the Department of Electrical Engineering.*) *D. J. Epstein*

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6.682-6.683 *Special Studies 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 requirement by the student and staff members interested, subject to approval of the professor in charge. (*Registration of non-Course* VI *students subject to approval of professor in charge.*) *D. J. Epstein*

6.684-6.689 *Special Subjects in Electrical Engineering* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Opportunity for group study of advanced subjects related to electrical engineering not otherwise included in curriculum. Programs subject to approval of professor in charge. *D. J. Epstein*

6.691J *Speech Communication* (A)
(Same subject as 23.768J)
Prereq.: ——
Year: G (2) 3–0–9
Survey of structural properties of natural languages with special emphasis on the sound pattern Survey of physiology of speech production, articulatory phonetics. Acoustical theory of speech production: the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic; acoustical and articulatory descriptions of phonetic features. Perception of speech: the auditory capabilities of man; evidence for perceptual correlates of phonetic categories. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. Recommended prerequisites: engineering and science students, 6.36T; linguistics students, mathematical background equivalent to 6.05 or 18.05. Others admitted by permission of instructor. *Stevens, Halle*

6.694J *Laboratory in the Physiology, Acoustics, and Perception of Speech* (A)
(Same subject as 23.766J)
Prereq.: ——
Year: G (2) 0–6–6
Experimental investigations of speech processes. Measurement of pressure and volume velocity during speech. Interpretation of X-ray motion pictures. Computer-aided analysis and display of acoustic waveforms and spectra, spectrographic analysis, acoustic correlates of distinctive features. Problems in automatic speech recognition; techniques of speech synthesis; studies of speech perception. *Klatt, Halle*

6.70 *Electronic Components and Measurements*
Prereq.: 6.01
Year: U (1, 2, S) 1–4–1
Required laboratory for electrical engineering students. Laboratory work concerned with meters, components, oscilloscopes and other equipment necessary to make common measurements of electrical parameters. *Roberge*

6.71 *Electronic Circuits and Signals Laboratory*
Prereq.: 6.70
Year: U (1, 2, S) 1–4–1
Experiments on electric and electronic circuits and systems. *Schreiber*

6.711 *Digital Systems Project Laboratory*
Prereq.: 6.01, 6.70
Year: U (1, 2) 2–8–2
Introduction to some of the basic techniques and devices used in the design and implementation of digital computing and control systems. Preliminary work by a combination of classes, homework, and associated laboratory experiments with digital integrated circuits. Detailed study of logic design, including Boolean algebra, synthesis of combinational logic, iterative logic realizations, and techniques for description and syntheses of sequential circuits; other topics, such as memory devices, if time permits. Implementation of all projects with microcircuit logic elements. Oral presentation and written report on completion of project. (*Registration limited to 40 students.*) *Troxel*

6.712 *Bioelectronics Project Laboratory*
Prereq.: 6.01, 6.02
Year: U (1) 2–8–2
Emphasis on design of electronic circuits and systems useful in medicine, biology, or psychology. Background material to introduce the student to some of the problems in medicine and electrophysiology. Discussion of the physiological basis of electrical potentials in living systems. Examples of useful instrumentation techniques. First half on acquiring physiological background and developing a familiarity with the design of amplifiers, oscillators, filters, switching and pulse circuitry and digital systems. One lecture each week on the life sciences and a second lecture on circuit design with accompanying laboratory exercises and demonstrations. Second half on individual project directly applicable to some problem in the life sciences and group projects involving relatively sophisticated systems with student contribution of a functional component. Selection of projects on the basis of their educational properties and on their possibility of being actually useful. Opportunity of collaboration with a Boston-area hospital. Oral presentation and written report on completion of project. (*Registration limited to 20 students.*) *Burns*

6.714 *Electronic Light Measurements Project Laboratory*
Prereq.: 6.02
Year: U (1, 2) 2–8–2
Principles of the use of light and radiation in pulse form for photography, measurement, and energy conversion. Study and use of instruments for the evaluation of pulsed light sources for spectral content, efficiency, and pulse duration. Theory of electronic flash lamps and their application to stroboscopes, photographic light sources, laser stimulators, and instrumentation devices. Use of flash photography to identify and determine position, velocity, and acceleration of objects in space. Frequent laboratory and demonstration experiments to illustrate application of techniques to engineering and scientific measurements. (*This subject is a project laboratory version of 6.202.*) *Edgerton*

6.715 *Power Systems Project Laboratory*
Prereq.: 6.01, *6.03*, 6.70
Year: U (1, 2) 2–8–2
Introduction to the concepts and techniques used in power systems engineering. First three weeks: lectures describing power system technology and the projects currently available. Student's choice (either alone or with lab partners) of a project; independent work involving linear and non-linear circuits both passive and active, electromagnetic phenomena, electromechanical phenomena, etc., all in a power system context. (*Limited enrollment.*) *Woodson, G. L. Wilson*

6.716 *Particle Optics Project Laboratory*
Prereq.: 6.03
Year: U (2) 2–8–2
Special projects involving low energy electrons and ions and their interactions with fields and surfaces. Typical projects: design and testing of mass spectrometers, low magnification electron microscopes, high power beams, electron multipliers, and special cathode ray tubes. Other studies concern secondary emission, electron diffraction, microminiaturization of computer components using electron induced chemistry, thin films, or other areas of interest. (*Limited enrollment.*) *Crawford*

6.717 *Audio Frequency Communications Project Laboratory*
Prereq.: 6.05, 6.571, 6.70
Year: U (1, 2)
Introduction to some of the more common techniques and methods for the transmission or storage of information carrying signals. Application of systems analysis, information theory, and circuit design to the development of communications systems. Emphasis on the interrelationship between bandwidth, noise, energy, cost, size, reliability, effectiveness, etc. Illustrative examples, including RF transmitters and receivers, tape recorders, companders, vocoders, compressers, human speech, to be discussed in seminar-like recitations. Laboratory experiments on modulation and operational amplifiers and organization of a problem in communications which can be turned into a project. Oral and written presentation of the project. *Troxel*

6.718 *VHF Circuits Project Laboratory*
Prereq.: 6.03, 6.341, 6.70
Year: U (1) 2–8–2
Study of designs of wideband amplifiers, tuned amplifiers, and non-linear circuits such as mixers. Construction of these circuits with bi-polar transistors, VHF integrated circuits, and field-effect transistors. (*Limited enrollment.*) *Wedlock*

6.719 *Semiconductor Devices and Circuits Project Laboratory*
Prereq.: 6.02
Year: U (1, 2) 2–8–2
Term project involving the fabrication of semiconductor devices and/or integrated circuits. Introduction to techniques of solid-state diffusion, oxide masking, photolithographic techniques, and thin film deposition, followed by individual project work in one or more of the above areas, or in the fabrication and evaluation of such semiconductor devices as integrated capacitors and resistors, Schottky-barrier diodes, planar diodes, or transistors. (*Limited enrollment.*) *Smythe*

6.721 *Advanced Digital Systems Project Laboratory*
Prereq.: 6.252; 6.70 or 6.711
Year: U (2) 2–8–2
Logical design, structure, and operation of digital systems with emphasis on small stored program computers. Classes and homework preliminary to projects covering several topics: description of digital systems which have too many states to be described by state diagrams, functional decomposition into manageable units, and techniques for the design of arithmetic, control, and memory elements. Implementation of projects with microcircuit logic. Individual oral presentation and project report a requirement. (*Registration limited to 16 students. Permission of instructor required.*) *Troxel*

6.722 *Modern Optics Project Laboratory*
Prereq.: 6.03, 6.05
Year: U (2) 2–8–2
Emphasis on coherent optical systems, quantum electronics, and optical information processing and transmission. Lectures and demonstrations preliminary to projects: properties of light, imaging and transforming properties of a lens, practical optical systems, optical measurements, lasers, optical detectors, holography, optical modulation and communication. Project areas: optical filtering, holography, optical communication, lasers, and quantum noise. Oral presentation and written report. (*Limited enrollment.*) *Hoversten*

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. *Woodson*

6.79 *Special Problems in Computation*
Prereq.: 6.47
Year: U (1, 2) *Arr.*
Individual work in computer science at the undergraduate level. Note: Acceptable ability to program a computer will satisfy the 6.47 prerequisite. *Saltzer*

6.80 *Special Studies in Electrical Engineering*
Prereq.: ——
Year: U (1, 2) *Arr.*
Opportunity for individual study at the undergraduate level related to electrical engineering not covered by other subjects offered by the department.
Troxel, Wedlock

6.81 *Electrical Engineering Laboratory*
Prereq.: ——
Year: U (1, 2) *Arr.*
Experimental work at the undergraduate level.
Troxel, Wedlock

6.82 *Undergraduate Thesis Presentation*
Prereq.: ——
Year: U (1,2) *Arr.*
Registration for written and oral presentation of the undergraduate thesis when the thesis work is an extension of a project laboratory. *Kyhl*

6.831-6.839 *Teaching Electrical Engineering* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For qualified graduate students interested in teaching as a career. Laboratory, tutorial, or classroom teaching under the supervision of a faculty member. Students selected by interview. Total enrollment limited by availability of suitable teaching assignments. *Bruce*

6.841-6.849 *Research in Electrical Engineering* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For Research Assistants in electrical engineering in cases where the assigned research is approved for academic credit by the Department. Hours arranged with research supervisor. *Searle*

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6.881-6.883 ***Industrial Practice at AVCO Corporation***
Year: U (1, 2, S) 0–9–0

6.884 ***Industrial Practice at AVCO Corporation***
Year: G (S) 0–9–0

Work at Everett, Massachusetts, in high-temperature gas dynamics. Research areas including space-vehicle re-entry missile defense, space propulsion, electric power generation through magnetohydrodynamics (MHD), and fundamental investigations of interplanetary plasma characteristics. Work organized into aerophysics, dealing with solution of aerodynamic-flow problems involving physical phenomena inherent in high-temperature gases; atomic physics, dealing with atomic and molecular processes of high-temperature gases (principally air and its constituents); magnetohydrodynamics, dealing with interactions between plasmas and magnetic fields. *Reintjes*

6.885 ***Industrial Project at AVCO Corporation***
Year: U (2) 0–12–0

Project to satisfy requirements of S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.891-6.893 ***Industrial Practice at Radio Corporation of America***
Year: U (1, 2, S) 0–9–0

6.894 ***Industrial Practice at Radio Corporation of America***
Year: G (S) 0–9–0

Work at Research Center and Astro-Electronics Division of R.C.A. Laboratories in Princeton, New Jersey. Exploration of electronically active solid materials; application of new principles in solid-state devices; creation of new or improved equipment for communications and broadcasting; research in energy conversion; development of new computing techniques, devices, and systems; studies in electron-tube and plasma devices; applied research, development, and design of space-vehicle systems; antennas; thermodynamics; optical systems; systems synthesis and analysis; data processing for operations research analysts and programming analysts. *Reintjes*

6.895 ***Industrial Project at Radio Corporation of America***
Year: U (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.90 ***Industrial Project at the General Electric Company***
Year: U (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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 Pittsfield, Schenectady, and Philadelphia. 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 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 (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

6.911-6.913 ***Industrial Practice at Honeywell, Incorporated***
Year: U (1, 2, S) 0–9–0

6.914 ***Industrial Practice at Honeywell, Incorporated***
Year: G (S) 0–9–0

Work assignments at the Electronic Data Processing Division, Wellesley, Massachusetts; Radiation Center, Boston, Massachusetts; and at plant locations in Minneapolis, Minnesota. At Wellesley, opportunities relating principally to the design and development of digital computer circuits and systems and computer software. At the Radiation Center, assignments involving electro-optic sensors and related control, and information processing systems. In Minneapolis, assignments involving a wide variety of experiences in automatic control, electronic circuitry and systems, and instrumentation for space, military, and industrial applications. *Reintjes*

6.919 ***Industrial Project at Honeywell, Incorporated***
Year: U (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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*

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 ferromagnetics; acoustics, and microwave electronics. *Reintjes*

6.939 ***Industrial Project at the Raytheon Company***
Year: U (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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, Holmdel, or Whippany, New Jersey). 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 (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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 (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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 (New York City). Work associated with the operation and planning of a large multistate 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 (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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 civilian employment with a branch of the Department of Defense following graduation. Acceptance optional. *Reintjes*

6.989 ***Industrial Project at the Naval Ordnance Laboratory***
Year: U (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *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 (2) 0–12–0

Project to satisfy requirements for S.B. thesis. Report required in the nature of a thesis report. For Program 2 students only. *Reintjes*

7.
Biology

7.00 ***Perspectives in Life Science***
Prereq.: ——
Year: U (2) 2–0–4

Lectures and readings presenting a general view of the broad area covered by the life sciences; emphasis on fundamental problems and current research from the

(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.

molecular level to the place of man in the world of living organisms; summary of current work underway by general biologists, biochemists, biophysicists, microbiologists, and investigators in many other sciences. Treatment of subjects such as the origin of life; the chemistry of living things; the transfer of genetic information; growth and development; cellular, organismal, and environmental control mechanisms; and modern methods and techniques used in the life sciences. Planned for students electing the life sciences as a major field or as a survey for students planning to major in other fields. *B. S. Gould*

7.01 *General Biology*
Prereq.: ——
Year: U (1) 4–0–8
Introduction to biology — lectures and demonstrations. Part 1: Molecular biology using examples from work done with bacteria and viruses; introduction to synthesis of small molecules and macromolecules to enzymes and various aspects of cellular control systems, biochemical energetics, and genetics. Part 2: Evolution of more complicated processes in simple multicellular organisms; evolution and classification of plants and animals. Part 3: Higher organism physiology; interactions of organisms with their unfriendly environment. Emphasis on detectors and effectors which enable the organism to respond to both predictable and non-predictable changes in environment. *Luria, Gross*

7.02 *General Biology Laboratory*
Prereq.: 7.01
Year: U (2) 1–8–3
Four projects to introduce experimental biology; work in molecular biology, cell biology, and neurophysiology. Two projects, with detailed instruction, from recent research literature. Two other projects with student given some choice in problem and approach. Techniques taught as needed.
Holt, J. E. Brown, Baltimore

7.03 *Genetics*
Prereq.: 7.21
Year: U (2) 3–0–6
Continuity and variation in the multiplication of living organisms. Mutation and selection as a mechanism for biological change. Principles of formal genetics. Physical and chemical basis of heredity. Structure and function of the hereditary material. Molecular basis for mutation, genetic function and recombination in microorganisms. *Signer*

7.031 *Genetics and Microbiology Laboratory*
Prereq.: 7.21
Year: U (2) 1–6–2
A project-type laboratory subject to teach the techniques employed in current microbial and genetic research including experiments on mutagenesis, isolation and characterization of mutants, mating, transduction, transformation, localization of genetic markers, complementation and recombination, analysis of biochemical pathways using mutants, isolation of ascospores and analysis of Neurospora crosses, chromosome karyotyping, preparation and analysis of pedigrees. *Yankofsky, Signer*

7.04 *Developmental Biology*
Prereq.: 7.02, 7.05
Year: U (1) 2–0–4
Mechanics and principles of development of selected invertebrate and vertebrate organisms. Biochemical and structural differentiation of cells, tissues, and organs. Review of experiments on metabolism, growth, movements, and interactions of cells and other components of developing systems. *Bell*

7.041 *Cell Biology Laboratory*
Prereq.: 7.02, 7.05
Year: U (1) 1–6 2
A project laboratory to introduce the student to the molecular basis of cell function, with emphasis on experimentation with protozoan and metazoan cells. *Baglioni*

7.05 *General Biochemistry*
Prereq.: 5.41
Year: U (1) 4–0–6
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 (2) 0–8–0
Laboratory exercises to illustrate principles discussed in 7.05. Allotment of some time to projects with some choice given as to the nature of the project and the experimental approach. *B. S. Gould, G. M. Brown*

7.06 *General Physiology*
Prereq.: 5.60, 7.01, 7.05
Year: U (2) 3–0–6
Physical and chemical basis for molecular structure and relationship between structure and function in living systems. General principles 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. *Penman, Gross*

7.061 *General Physiology Laboratory*
Prereq.: 7.06
Year: U (2) 0–6–0
Laboratory investigation of physiological processes.
(Not offered in 1968–69.) *Pomeranz*

7.08 *Introduction to Biophysics*
Prereq.: 7.00 or 7.01; 8.02
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. *D. F. Waugh*

7.21 *General Microbiology*
Prereq.: 7.01, 7.05 or 7.71
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*

7.23 *Microbial Physiology* (A)
Prereq.: 7.21
Year: G (2) 3–0–7
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*

7.24 *Topics in Bacteriology* (A)
Prereq.: 7.23, 7.86
Year: G (1) 2–0–6
Recent developments in bacteriology: genetic, regulatory and macromolecular processes.
Fox, Magasanik, Yankofsky

7.25 *Topics in Virology* (A)
Prereq.: 7.21, 7.86
Year: G (2) 2–0–6
Biological and molecular properties of bacteriophages and animal viruses. *Luria, Penman, Signer*

7.31 *Biology Seminar* (A)
Prereq.: 7.05 or *7.71*
Year: G (1) 2–0–4
Areas of biology that may have been deficient in students' undergraduate preparation. The relation between the molecular and classical aspects of cellular physiology, genetics, and microscopic anatomy. Training of students in oral presentations and in the leading of group discussions. *Staff*

7.32 *Biology Seminar* (A)
Prereq.: 7.05 or 7.71
Year: G (2) 2–0–4
Continuation of 7.31.

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. *Staff*

7.50 *Physical Chemistry of Macromolecules* (A)
Prereq.: 5.60, 7.05
Year: G (2) 2–0–4
Emphasis on macromolecules of biological origin, particularly proteins and nucleic acids. Discussion of physical techniques (such as diffusion, ultracentrifugation, osmotic pressure, light scattering, electrophoresis, viscosity, spectrophotometry, optical rotatory dispersion) with respect to theory and contemporary developments in two major areas: (1) molecular size, shape and solvation and (2) internal structure, surface structure, intermolecular forces and specific and non-specific molecular interaction. *D. F. Waugh*

7.51T *Organ and System Physiology*
Prereq.: ——
Year: U (1) 3–0–6
Study of the mechanisms of cell-cell interaction and the physiology of organ systems, starting with a study of detectors of the state of the internal and external environment and continuing to examine chemical and mechanical effectors. Lectures on comparative functional anatomy, experimental methods, the sensory analysis of events, the generation of action patterns, and the normal and pathological behavior of whole systems. Open to selected graduate students from other departments provided they have taken 7.01 or its equivalent. A special section to be arranged if sufficient students interested in quantitative system analysis register.
Lettvin

7.68T *Advanced Biochemistry Laboratory* (A)
Prereq.: 7.05 or *7.71*
Year: G (1) 1–8–3
A project laboratory with emphasis on experimental design and analysis in biochemistry. Projects based on procedures used in the study of structures and functions of carbohydrates, lipids, proteins and nucleic acids. Experiments dealing with problems in enzymology, oxidative phosphorylation, and nucleic acid metabolism.
K. B. Taylor

7.69 *Seminar in Biochemistry* (A)
Prereq.: 7.71
Year: G (2) 2–0–4
Reading and reporting of reviews and recent publications in biochemistry. Designed to be taken simultaneously with 7.72. (*Permission of instructors required.*)
Robbins, Buchanan

7.70 *Seminar in Protein and Nucleic Acid Structure* (A)
Prereq.: 7.05 or 7.72
Year: G (1) 2–0–4
Preparation and discussion of students' papers on topics in protein and nucleic acid chemistry. Emphasis on chemical evidence for the structure of these substances and on relationships between structure, function, and genetic control in selected instances. *Ingram*

7.71 *Biochemistry* (A)
Prereq.: 5.41
Year G (1) 4–0–8
Discussion from biological and chemical points of view of the structure and function of macromolecules, energy transfer systems, and intermediary metabolism. The chemistry of biologically important compounds with emphasis on proteins and nucleic acids, including considerations of secondary and tertiary structures as well as problems of primary sequence and the chemistry of amino acids and nucleotides. Other major topics: energy metabolism, the biochemistry of photosynthesis and photophosphorylation and the intermediary metabolism of carbohydrates. Discussion of electron transfer reactions and lipid metabolism from the point of view of the function of biological membranes. *Staff*

7.72 *Advanced Biochemistry* (A)
Prereq.: 7.05 or 7.71
Year: G (2) 4–0–8
Continuation of 7.71 with emphasis on enzyme mechanisms and the biosynthesis of macromolecules and their precursors. Discussion of enzyme mechanisms including new approaches to the chemical structure of active sites of enzymes and the kinetic analysis of enzyme action. All major metabolic pathways involved in the synthesis and degradation of amino acids, purines, pyrimidines, porphyrins, and coenzymes with emphasis on the mechanisms of individual enzymatic reactions and problems of physiological control. Consideration of the synthesis of proteins and nucleic acids from the points of view of the enzymology of the relevant reactions, the relation of RNA metabolism to protein synthesis, and the structure and function of the ribosome. *Staff*

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. (*Not offered 1968–69.*)
Staff

7.811 *Enzymology Laboratory* (A)
Prereq.: 7.81
Year: G (2) 0–4–2
Methods of purification of enzymes; determination of their catalytic activities and chemical properties; effects of environmental factors on enzymes. (*Not offered 1968–69.*)
Staff

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7.85 ***Optical Methods in Biophysics*** **(A)**
Prereq.: 8.03T
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.: 7.21
Year: G (2) 3–0–9
Review of recent experimental and theoretical developments in molecular genetics. 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. *Signer*

7.911 ***Instrumentation and Research Methods*** **(A)**
Prereq.: 8.03T
Year: G (1) 2–0–4
Introduction to the analysis of physical research methods and instrumentation for scientific research in the life sciences, medical research, and certain aspects of industrial biology. Principles of the basic electrical instrumentation elements. *Lion*

7.912 ***Instrumentation and Research Methods Laboratory*** **(A)**
Prereq.: 8.03T
Year: G (1) 0–4–0
Laboratory complementary to 7.911. *Lion*

7.92 ***Advanced Instrumentation*** **(A)**
Prereq.: 7.911, 7.912
Year: G (2) 0–4–0
Analysis and synthesis of new research methods, systems, and instruments for scientific research in the life sciences, medicine, and certain aspects of industrial biology. *Lion*

7.93 ***Selected Topics in Biology*** **(A)**
Prereq.: ——
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 8.03T
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: 7.95
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*

7.99 ***Molecular Configuration in Biological Systems Seminar*** **(A)**
Prereq.: 7.05 or 7.72
Year: G (2) 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. Special emphasis on molecular structure of crystalline proteins and nucleic acids. *Rich*

8.
Physics

GENERAL UNDERGRADUATE SUBJECTS

8.001 ***Introduction to Physical Ideas***
Prereq.: ——
Year: U (1) 2–0–4
Introduction to the ideas of kinematics and dynamics. Exploration of the relationship between mathematical models and physical reality. Intended primarily for first-year students who elect to take Physics I (8.01) in the second term. *Staff*

8.01 ***Physics I***
Prereq.: ——
Year: U (1, 2) 5–0–7
Particles: electrons, atoms and molecules, ions and nuclei; randomness; photon and wave properties of light; macroscopic particles. Newtonian mechanics: motions and forces; frames of reference; momentum and energy; conservation principles; conservative forces and linear oscillations; central forces; orbits; angular momentum and rotating bodies. Although Mathematics 18.01 is not a stated prerequisite for Physics 8.01, a majority of those students of previous years who received honor grades had already had a background subject in differential and integral calculus. *Staff*

8.02 ***Physics II***
Prereq.: 8.01
Year: U (1, 2) 5–0–7
Relativity: deviations from Newtonian dynamics; Lorentz-Einstein transformations; relativistic dynamics. Electromagnetism: electrostatics and field concepts; electric currents and magnetic fields; induction laws; field energies; Maxwell's equations; circuit electricity; electromagnetism and relativity. *Staff*

8.03T ***Physics III***
Prereq.: 8.02
Year: U (1, 2) 5–0–7
Mechanical vibrations and waves: periodic motions and their superposition; free vibrations; forced vibrations and resonance; coupled oscillations and normal modes; vibrations of continuous systems; progressive waves; reflexion, refraction and diffraction (with Huygens' principle.) Electromagnetic waves and optics: plane wave solutions of Maxwell's equations; polarization; transparent media and refractive index; boundary conditions at conductors and dielectrics; cavity resonance and wave guides; fields of accelerated changes; examples of wave and ray optics. *Staff*

8.04 ***Principles of Quantum Physics***
Prereq.: 8.03T
Year: U (1, 2) 5–0–7
Concept of quantum state, illustrated with two state systems: photon polarization and electron spin. Probability amplitude. Superposition principle. States, operators and their matrix representations. Time dependence of states; precession of spin in magnetic field. Description of particle motion. Amplitudes for position and momentum. Wave packets and the uncertainty principle. Wave equation for free particle. Particle in a field of force; Schroedinger equation. Quantization of energy and angular momentum; the hydrogen atom. Schroedinger equation in matrix form: Hyperfine structure and magnetic resonance. *Staff*

8.05 *Physics of Atoms and Molecules*
Prereq.: 8.04
Year: U (1, 2) 4–0–8
Experimental basis of quantum physics, with examples mainly from atomic, molecular and radiation dynamics. Hydrogen like atoms: spin orbit splitting; Zeeman and Stark effects. Emission and absorption of radiation: microwave, infrared, optical and X-ray spectra. Selection rules and the Correspondence principle. — Many electron atoms. The Pauli exclusion principle; the periodic system of elements. — Diatomic molecules. Rotational and vibrational spectra. Symmetry effects, para- and ortho hydrogen. Qualitative theory of molecular binding, and the structure of solids. *Staff*

8.06 *Theoretical Physics I*
Prereq.: 8.04
Year: U (2) 4–0–8
Basic concepts of mechanics: Inertial frames of reference; space, time, mass, force. Types of forces. Equations of motion. Conservation laws for closed systems. Non-inertial frames of reference. — Planetary motion. Harmonic oscillator. Macroscopic objects: Constraints; Hamilton's principle and Lagrange's equations. Rigid body dynamics. Coupled oscillators, Green's functions. Normal modes; continuum limit: elastic strings, solids; fields. Canonical variables, Hamilton's equations, Poisson bracket equations of motion. Principle of least action; Hamilton-Jacobi equation. Survey of electrodynamics: Basic phenomena and systems of units. Maxwell's equations; simple applications: oscillating circuits, coaxial cables. Moving frames of reference, the Lorentz group. Energy momentum four-vectors, field tensors and relativistic equations of motion. *Ingard*

8.07T *Theoretical Physics II*
Prereq.: 8.06
Year: U (1) 4–0–8
Electromagnetic waves: plane waves, polarization. Huygens' principle, Kirchhoff approximation, diffraction. Energy, momentum, angular momentum of wave packets. Spherical waves; wave guides. — Inhomogeneous wave equations. Green's function solution, Causality. Periodic charge-current distributions, $v/c \ll 1$ limit. Lienard-Wiechert potentials. Synchrotron radiation. Facts of quantum physics. Qualitative quantum mechanics. Classical limit; measurements and interpretation of x. Systems with discrete spectra: harmonic oscillator, time-dependent solutions, classical limit. Angular momentum; scalar and vector operators. Diatomic molecules. The continuum: scattering of wave packets; scattering amplitude and cross sections. Quantum theory of radiation: photons, operators for E and B fields, classical limit. Emission, absorption and scattering of radiation; selection rules. *K. Huang*

8.08T *Theoretical Physics III*
Prereq.: 8.07T
Year: U (2) 4–0–8
Quantum systems of identical particles. Pauli principle. Occupation number representation of Boson- and Fermion-states. Kinetic Theory: Phase space, Liouville theorem, Boltzmann equation. H-theorem. Ideal gas: work, heat, entropy. Transport phenomena. Thermodynamics: state variables, equations of state. First Law. Second Law; entropy maximum principle, reversible and irreversible processes. Thermodynamic temperature. Ideal gas and photon gas. Thermodynamic potentials, Maxwell relations. Simple and composite systems, phase transitions and chemical equilibrium. Statistical mechanics: ensembles and entropy. Canonical ensemble, partition function in classical and quantum mechanics. Bose and Fermi gas, Boltzmann limit. Specific heats, electric and magnetic susceptibilities. Fluctuations, noise, and Nyquist theorem. *K. Huang*

UNDERGRADUATE LABORATORY AND SPECIAL PROJECT SUBJECTS

8.11T *Physics Project Laboratory I*
Prereq.: ——
Year: U (1) 1–6–5

8.12T *Physics Project Laboratory II*
Prereq.: ——
Year: U (2) 1–6–5
Laboratory work with close faculty guidance but emphasizing independent work and a professional approach. Study of various physical systems and interpretation of observed effects; construction of high-vacuum apparatus to study electrons, ions, and atoms; and growing of single crystals and study of some of their properties. *Staff*

8.13T *Experimental Atomic Physics I*
Prereq.: 8.04
Year: U (1) 0–6–6
Laboratory experiments including both those fundamental to the development of modern physics and those which illustrate modern experimental techniques. Experiments ranging from measurement of the electron charge by Millikan's oil drop method to the use of scintillation counters to detect coincident γ-rays from positron annihilation. Other experiments including the Hall effect, thermionic emission and the T^4 dependence of radiated energy, the Faraday effect, and the Franck-Hertz experiment. Machine shop and vacuum techniques included as part of the experiments. In final weeks of term, experiments of the student's own choice. (*Limited primarily to students in Course* VIII.) *W. H. Moore*

8.14T *Experimental Atomic Physics II*
Prereq.: 8.13T
Year: U (2) 0–6–6
Continuation of 8.13T with emphasis on extending experimental experience to more sophisticated techniques and utilizing knowledge from 8.05. Experiments including X-ray and optical absorption, the Zeeman effect, optical pumping, nuclear magnetic resonance, Compton scattering, and Mössbauer scattering. *W. H. Moore*

8.15 *Experimental Physics*
Prereq.: 8.14T
Year: U (1) 2–0–2
Introduction to experimental research techniques by (1) lectures given by various members of the staff, and (2) individual presentation of research projects to whole group. Designed to bridge gap between elementary laboratory and research in modern physics. *Staff*

8.18T *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. *A. G. Hill*

8.19T *Readings in Physics*
Prereq.: ——
Year: U (1 or 2) *Arr.*
Supervised reading and library work. Choice of material and allotment of time according to individual needs. For students finding it desirable to do work not provided for in the regular subjects. Specific approval of Department Head required in each case. *A. G. Hill*

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UNDERGRADUATE ELECTIVE SUBJECTS

8.211 *Introduction to Quantum Physics*
Prereq.: 8.03T
Year: U (1, S) 4–0–8
Study of the experimental foundations of quantum physics and the quantum theoretical interpretation of atomic phenomena. *Staff*

8.222 *Group Theoretical Methods in Physics*
Prereq.: 8.05
Year: U (2) 3–0–9
Introduction to the theory of groups and group representations, physical applications. Finite groups: point and permutation groups. Continuous groups: rotation and Lorentz groups. Infinitesimal transformations. Angular momentum. Atomic structure and the vector model of the atom. Atoms and molecules in external fields. Evaluation of matrix elements. Wave functions of electrons in crystals. Electron spin. Dirac equation. Topics from high-energy physics, molecular structure and spectra, or nuclear physics. *Kolenkow*

8.231T *Introduction to Solid-State Physics*
Prereq.: 8.05, 18.05
Year: U (1) 3–0–9
Introduction to properties of solids, including structure and external symmetry properties of crystals; X-ray diffraction and microscopic crystal structure, binding energy in solids, elastic properties of continuous media; elastic waves in discrete lattices, temperature dependence of the physical properties of solids. Magnetic properties of solids, free electron theory of metals. *Strandberg*

8.232 *Topics in Quantum Theory of Matter*
Prereq.: 8.05
Year: U (2) 3–0–9
Elementary quantum mechanics applied to the study of real problems, largely from the field of solid-state physics. Review of exactly soluble problems. Approximation methods applied to many-electron atoms (Hartree-Fock), molecular binding, lattice structure of solids. Electronic states in solids: metals, semiconductors and insulators. Superconductivity: electron pairing, Meissner effect, flux quantization and Josephson junctions. Origin and nature of magnetism: ferro magnets at low temperature; qualitative discussion of critical points. *Litster*

8.241 *Electron Physics*
Prereq.: 8.04
Year: U (1) 4–0–8
Electron ballistics, mass spectroscopy; high-energy accelerators; space charge theory; Fermi-Dirac statistics, thermionic emission, Schottky effect, high field and secondary emission, photoelectric effect in metals; conductors, insulators, and semiconductors. *Harvey*

8.242 *Quantum Electronics*
Prereq.: 8.04
Year: U (2) 3–0–9
Fundamental processes in lasers and masers. Classical dipole radiation; susceptibility, and bulk properties of matter. Interaction of a quantum-mechanical two-level system with electromagnetic radiation. Laser oscillators. Excitation mechanisms in gaseous and solid-state lasers. Raman effect and non-linear optics. Laboratory demonstrations. Familiarity with Maxwell's equations and the Schroedinger equation a requirement. *Javan*

8.251T *Physics of Noise and Fluctuations*
Prereq.: 8.05
Year: U (1) 3–0–9
Mathematical description of random processes: joint probability distributions, correlation functions and power spectra. Fluctuations in discrete systems: shot noise, photon counting. Fluctuations about thermal equilibrium: space-time correlations of fluctuations of density, pressure, entropy, etc., and their relation to transport coefficients and dissipation constants. Discussion of modern experimental techniques for the study of thermal fluctuations. Quantum effects. Information theory. Fluctuations in living systems. *Greytak*

8.261 *Electrical Discharges in Gases*
Prereq.: 8.05
Year: U (1) 3–0–9
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. *Staff*

8.272 *Introduction to Nuclear Physics*
Prereq. 8.05 or 8.211
Year: U (2) 4–0–8
Elementary discussion of various topics of nuclear physics with description of selected experiments and discussion of results in light of current theories: two-nucleon systems, radioactive decay, nuclear reactions, and nuclear structure. *Staff*

8.281J *Planetary Physics*
(Same subject as 12.625J)
Prereq. 8.03T
Year: U (1) 3–0–9
Dynamical evolution of the solar system; perturbation theory; tidal forces; resonance interactions. Deduction of gravitational, surface, and atmospheric properties of planets and satellites from ground-based optical, radio and radar observations and from space-probe experiments. *I. I. Shapiro, McCord*

GRADUATE SUBJECTS

General Interest and Mathematical Physics

8.311T *Electromagnetic Theory I* (A)
Prereq.: 8.04, 18.05
Year: G (1) 4–0–8

8.312T *Electromagnetic Theory II* (A)
Prereq.: 8.311T
Year: G (2) 4–0–8
Maxwell's equations; static approximation; scalar potential, multipole expansion; boundary value problems; 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; Green's functions and causality; Huygens' principle, geometrical optics. Multipole radiation, radiation damping, "Bremsstrahlung." Special relativity. Covariant form of field equations and equations of motion. Potentials and gauge invariance. 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. *Staff*

8.321T *Quantum Theory I* (A)
Prereq.: 8.07T
Year: G (1) 4–0–8
Dynamics of particles and electromagnetic field in canonical form. Poisson brackets. Action and angle variables. Correspondence principle. Heisenberg matrices. Canonical commutation relations. Transformations of matrix representations and eigenvalue problems.

Quantum states and superposition principle. Probabilistic interpretation. Uncertainty relations. Non-stationary states; equations of motion. Heisenberg and Schroedinger picture; transitions; the classical limit. Central field problems; angular momentum; elementary scattering theory. *Staff*

8.322 *Quantum Theory II* (A)
Prereq.: 8.321T
Year: G (2) 4–0–8
Perturbation theory of stationary states. Symmetry and selection rules; rotations and tensor operators. Perturbation theory of non-stationary states. Adiabatic processes. Transition rates. Application to emission, absorption, and scattering of radiation and elastic and inelastic collisions. Systems of identical particles; method of "second quantization;" Hartree-Fock equations. General theory of scattering and reactions. T-matrix, variational, and other approximation methods. Unitarity conditions and S-matrix. *Staff*

8.323 *Quantum Theory III* (A)
Prereq.: 8.322
Year: G (1) 4–0–8
Relativistic kinematics; covariant equations of motion; dynamics of spin 0 particles; general concepts of relativistic quantum theory. Relativistic spin theory and Dirac equation. External field problems, scattering, polarization. Neutrinos and photons. Discussion of symmetry operations and symmetry properties of systems; CTP theorem. Quantum-, meso-, and electrodynamics. S matrix and Feynman rules. Chew-Low equation and elements of dispersion theory. *Staff*

8.331 *Analytical Mechanics* (A)
Prereq.: 8.03T, 18.05
Year: G (1) 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. *Staff*

8.333 *Statistical Mechanics I* (A)
Prereq.: 8.321T
Year: G (1) 4–0–8
Principles 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 collisions. 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. *Ingard*

8.334 *Statistical Mechanics II* (A)
Prereq.: 8.333
Year: G (2) 4–0–8
Quantum statistical mechanics: ensembles and density matrix. Ideal gases and selected elementary applications. Bose-Einstein condensation; imperfect gases. Introduction to the theory of Fermi liquids. Selected topics from the quantum mechanical many-body problem; non-equilibrium statistical mechanics. *Scully*

8.341T *Methods of Theoretical Physics I* (A)
Prereq.: 8.06, 8.311T
Year: G (1) 4–0–8
Review of fundamental partial differential and integral equations of physics. Complex variables, boundary values of analytic functions. Separation of variables. Ordinary differential equations in complex domain boundary conditions. Variational principles. Eigenfunctions, abstract vector space, Green's functions. Integral equations. Wiener-Hopf and Muskhelishvilli methods. (*Alternate years. Not offered 1968-69.*) *Morse*

8.342 *Methods of Theoretical Physics II* (A)
Prereq.: 8.341T
Year: G (2) 4–0–8
Continuation of 8.341T. Approximate methods; variational and perturbation methods applied to discrete spectra. Approximate methods for continuous spectra. Long wavelength and high-energy approximations. Scattering formalism for scalar equations. S-matrix theory. Analyticity of solutions in complex energy plane. Dispersion relations, causality, Mandelstam representation. Extension of scattering formalism to vector and tensor equations. Application to problems in electrostatics, hydrodynamics, acoustics, diffusion, electromagnetic waves, quantum mechanics. Perturbation theory for many-body problems. (*Alternate years. Not offered 1968-69.*) *Morse*

8.351 *Physical Applications of Group Theory I* (A)
Prereq.: 8.321T
Year: G (1) 3–0–9

8.352 *Physical Applications of Group Theory II* (A)
Prereq.: 8.351
Year: G (2) 3–0–9
Theory of groups and their representations. Discussions of point, rotation, space, Lorentz and Lie Groups. Applications to various branches of physics. (*Alternate years.*) *Staff*

8.391, 8.392 *Special Problems in Theoretical Physics* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Reading, consultation, and original investigation on a problem in theoretical physics. *Staff*

8.399 *Special Problems in Physics* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For graduate assistants in the Department of Physics where assigned research or teaching duties are approved for academic credit by the Department. *Staff*

Physics of Atoms, Radiation, Solids, Liquids and Plasma

8.411T *Advanced Atomic Physics* (A)
Prereq.: 8.321T
Year: G (1) 3–0–9
Theory of spectroscopy, including atomic and solid-state spectroscopy in optical and microwave regions. Angular momentum through the use of the Racah formalism. One-electron and many-electron atoms. Atoms in crystal lattices; the Stark and Zeeman effects; the effects of strain on crystal spectra. Experimental methods and results. (*Alternate years.*) *Koster*

8.421T *Introduction to Optical, Microwave, and Radiofrequency Physics* (A)
Prereq.: 8.321T
Year: G (1) 3–0–9
Theory of radio frequency, microwave, and optical methods for determining magnetic and electric moments of nuclei and the charge and spin distributions of atoms. Topics include motion of spins in d-c and oscillating magnetic fields, electron-nuclear interactions, molecular beam methods, nuclear magnetic resonance, fluctuation phenomena and relaxation, masers, emission and absorption of light, optical pumping, and a brief introduction to lasers. *Kleppner*

(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.

8.431 ***Physics of Quantum Electronics*** **(A)**
Prereq.: 8.321T
Year: G (1) 3–0–9
Interaction of electromagnetic radiation with matter. Stimulated emission and scattering of radiation. Semiclassical theory of the optical maser; non-linear optics; photon echo, etc. Quantum theory of radiation, theory of optical coherence and the quantum description of laser behavior. *Scully*

8.442 ***Statistical Optics and Spectroscopy*** **(A)**
Prereq.: 8.05, *8.08T*
Year: G (2) 3–0–9
Discussion of light as a statistical process and description of its spectrum by the modern concept of correlation functions. Interaction of light with photodetectors, modern techniques of spectral analysis: photon counting, self-beating, heterodyne beating. Brown-Twiss experiment. Principles of interference and spatial coherence. Applications to Fabry-Perot interferometers and Fourier transform spectroscopy. Theory of diffraction, and grating spectrometers. Spectrum of light scattered by thermal fluctuations in transparent media. *Benedek*

8.491T, 8.492 ***Special Problems in Physics of Atoms and Radiation*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Advanced problems in atomic, optical, microwave and radiofrequency physics, with assigned reading and consultation. *Staff*

8.511T ***Theory of Solids I*** **(A)**
Prereq.: 8.231T or 8.232; 18.05
Year: G(1) 4–0–8
Theory of phonons and lattice vibrations; X-ray and neutron scattering; band theory of solids. Electron theory of metals and Fermi-Dirac statistics. Boltzmann transport theory with applications to the flow of heat and electricity in metals and semiconductors. *Staff*

8.512T ***Theory of Solids II*** **(A)**
Prereq.: 8.511T
Year: G (2) 3–0–9
Formalism of many-body theory, applied to problems of solid-state physics. Theory of superconductivity and of superfluids. Theory of magnetism. Optical and magneto-optical properties of solids. Theory of semiconductors. *Staff*

8.541T ***Neutron Diffraction*** **(A)**
Prereq.: 3.12 or 8.551T
Year: G (2) 3–1–8
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.*) *Shull*

8.551T ***X-rays and Crystal Physics***
Prereq.: 8.05, 18.06
Year: G (1) 3–0–9
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*

8.552T ***X-ray Diffraction*** **(A)**
Prereq.: 8.551T
Year: G (2) 3–0–9
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*

8.581, 8.582 ***Selected Topics in the Theory of Solids*** **(A)**
Prereq.: 8.512T
Year: G (1, 2) 3–0–9
Topics in solid-state theory varying from year to year. *Staff*

8.591, 8.592 ***Special Problems in Solid-State Physics*** **(A)**
Prereq.: ——
Year: G (1 or 2) *Arr.*
Advanced problems in the physics of the solid state, with assigned reading and consultation. *Staff*

8.611 ***Introduction to Physics of Fluids and Plasmas*** **(A)**
Prereq.: 8.08T
Year: G (1) 3–0–9
Properties of liquids, gases, and plasmas. Interaction forces. Equations of motion, particle vs. continuum description. Linear theory of waves and oscillations. Coupling between mechanical and electromagnetic waves. Energy loss mechanisms. Thermal relaxation effects. Landau damping. Non-linear effects. Interaction of waves. Shock waves. Instabilities. Classification of instabilities in liquids, gases, and plasmas. Introduction to the theory of turbulence. *Staff*

8.621J ***Plasma Kinetic Theory*** **(A)**
(Same subject as 22.68J)
Prereq.: 8.611 or 8.622
Year: G (1) 3–0–9
Content varying from year to year. Typical subjects: the linearized Vlasov equation, Fokker-Planck and diffusion approximations for the average distribution function, autocorrelation functions, resonant and non-resonant diffusion, free energy, energy and momentum conservation, resonant wave coupling, non-linear Landau damping, strong turbulence theories. Selected applications to enhanced diffusion, stochastic acceleration, turbulent resistivity, shock waves, radio emission. *Dupree*

8.622 ***Wave Propagation in Plasmas*** **(A)**
Prereq.: 8.08T; 8.261 or 8.611
Year: G (2) 3–0–9
Waves in a cold homogeneous plasma in a magnetic field, with the numerous approximations frequently described as separate "waves." Linearized Boltzmann treatment of electron and ion waves. Special cases of inhomogeneous media and non-linear waves. The shock-wave limit. (*Alternate years.*) *Allis*

8.632 ***Interactions of Plasmas with Electromagnetic Waves*** **(A)**
Prereq.: 8.08T
Year: G (2) 3–0–9
Propagation of transverse electromagnetic and longitudinal waves in infinite and bounded plasmas. Special emphasis on experimental methods and the interpretation of results insofar as these provide information about the physical behavior of the plasma medium. Discussion of the following topics: optical, laser, infrared and

microwave interferometry; resonant cavity techniques; laser and microwave scattering from density fluctuations; bremsstrahlung, cyclotron and Cerenkov emission and absorption; longitudinal electron plasma and ion-acoustic waves in isotropic and magneto-active plasmas; beam-plasma interactions and instabilities. *S. C. Brown*

8.681, 8.682 *Selected Topics in Plasma Physics* (A)
Prereq.: 8.611
Year: G (1, 2) 3–0–9
Presentation of subjects of current interest, with topic varying from year to year. *Staff*

8.691, 8.692 *Special Problems in Fluid and Plasma Physics* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Advanced problems in fluid or plasma physics with assigned reading and consultation. *Staff*

Nuclear and Particle Physics

8.711T *Nuclear Physics I* (A)
Prereq.: 8.05, 8.06
Year: G (1) 3–0–9
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. *Staff*

8.712 *Nuclear Physics II* (A)
Prereq.: 8.711T
Year: G (2) 3–0–9
Continuation of 8.711T. 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. Nuclear spectroscopy. *Staff*

8.721T *Nuclear Physics for Engineers I* (A)
Prereq.: 8.05 or 8.211
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. *Kolenkow*

8.722T *Nuclear Physics for Engineers II* (A)
Prereq.: 8.721T
Year: G (2) 3–0–9
Continuation of 8.721T. 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. *Kolenkow*

8.724 *Statistical Fluctuations in Physical Processes* (A)
Prereq.: 8.05
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 non-parametric tests. *R. D. Evans*

8.751 *Theory of Nuclear Structure I* (A)
Prereq.: 8.322
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. The three-body problem. The nuclear many-body problem: Hartree-Fock approximation; Bruecker-Bethe Goldstone many-body theory, and its application to nuclear matter and finite nuclei. The nuclear shell model. (*Alternate years.*) *Feshbach*

8.752 *Theory of Nuclear Structure II* (A)
Prereq.: 8.751
Year: G (2) 3–0–9
Continuation of 8.751. Nuclear spectroscopy: collective and simple particle excitations; the random phase approximation. Electromagnetic interaction, sum rules. Theory of nuclear reactions: resonance reactions and the Breit-Wigner formula; doorway and analog states. Theory of the optical potential. Interaction of nuclei with elementary particles. (*Alternate years.*) *Feshbach*

8.781, 8.782 *Selected Topics in Nuclear Theory* (A)
Prereq.: 8.751
Year: G (1 or 2) 3–0–9
Presentation of subjects of current interest in nuclear structure and reaction theory. Intended to be given once a year by Department members and (or) visiting professors. *Staff*

8.791T, 8.792T *Special Problems in Nuclear Physics* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Research and reading with consultation in the general area of experimental or theoretical nuclear physics. *Staff*

8.811 *Particle Physics I* (A)
Prereq.: 8.05, *8.321T*
Year: G (1) 3–0–9
Observation and classification of elementary particles. Relativistic kinematics of particle reactions. Symmetry principles, conservation laws and invariance principles: charge, energy, momentum, angular momentum, parity, time reversal, charge conjugation, TCP theorem, isotopic spin, charge symmetry, G parity, strangeness, baryonic and leptonic numbers. Strong interactions of π mesons with nucleons, πp scattering. Baryonic and mesonic resonances; quantum number determinations. Strange particles; associated production, strange resonances. *Osborne*

8.812 *Particle Physics II* (A)
Prereq.: 8.811
Year: G (2) 3–0–9
Continuation in depth of 8.811 with particular emphasis on conservation laws and theoretical prediction in weak decays. Review of the most recent theoretical and experimental results in particle interactions and decays. *Feld*

8.822 *Theoretical Particle Physics* (A)
Prereq.: 8.323
Year: G (2) 3–0–9
Presentation of the basic techniques used in theoretical particle physics: static models; dispersion relations and the Mandelstam representation; helicity formalism. Complex angular momentum. Symmetries: current algebras and sum rules. *Gerstein*

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8.871, 8.872 *Topics in Relativistic Quantum Theory* (A)
Prereq.: 8.323
Year: G (1 or 2) 3–0–9
Precise material to be covered to differ from year to year according to interest of the instructor. Typical subjects: quantum field theory, S-matrix theory, single and double dispersion relations, Regge-poles, approximate symmetries, and weak interactions. *Staff*

8.881, 8.882 *Selected Topics in Particle Physics* (A)
Prereq.: 8.811
Year: G (1, 2) 3–0–9
Topics in particle physics, varying from year to year. *Feld*

8.891, 8.892 *Special Problems in Elementary Particle Physics* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Research and reading with consultation in the general area of experimental or theoretical particle physics. Experimental work which may involve use of off-campus facilities such as the Cambridge Electron Accelerator, Brookhaven National Laboratory, Stanford Linear Accelerator Center, or cosmic ray stations. *Staff*

Space- and Astro-physics

8.911 *Charged Particles in Space* (A)
Prereq.: 8.07T
Year: G (1) 3–0–9
Outline of properties of space beyond earth's atmosphere. Motion of charged particles in magnetic fields: Stormer's theory, Alfvén's approximation, adiabatic invariants. Geomagnetic effects on cosmic rays. Radiation belts. Collision cross sections and diffusion coefficients pertinent to physics of space. Physical quantities that characterize plasma; macroscopic versus microscopic description. Boltzmann Equations for fully ionized gases; moments of Boltzmann Equations; the generalized "Ohm's Law"; magnetohydrodynamic approximation. Elements of shock theory for dilute plasmas. *Olbert*

8.921 *Physics of the Stars* (A)
Prereq.: 8.05, 8.08T
Year: G (1) 3–0–9
Observable stellar characteristics and a survey of star types. Interpretation of the observations as suggested by theoretical studies of stellar structure and evaluation. An examination of physical processes in the stellar interior: matter and radiation under stellar interior conditions; nuclear transformations and modes of energy generation appropriate to quasi-static stages of evolution; photon absorption cross-sections and modes of energy transfer. Simple models describing gravitationally contracting, main sequence, and white dwarf stages. Stellar atmospheres and the determination of surface chemical composition. Final reexamination of the observations in the light of processes discussed. *Iben*

8.922 *Stellar Evolution and Nucleosynthesis* (A)
Prereq.: 8.921
Year: G (2) 3–0–9
Properties of stars during quasi-static phases of evolution through hydrogen burning, helium burning, and carbon and oxygen burning; helium and carbon flash phenomena; stages involving the α, e, r, and s processes of nucleosynthesis; phases dominated by neutrino losses; dynamic evolution induced by the Fe-He phase change; massive stars, super novae, white dwarfs; neutron stars; final stellar states. (*Alternate years.*) *Iben*

8.932 *Physics of the Galaxy* (A)
Prereq.: 8.911 or 8.921
Year: G (2) 3–0–9
Stellar content of the galaxy; kinematical results and dynamical theory. Gas content: gravitational and optical methods; optical polarization and dust. Galactic radio astronomy: spectroscopy of H, OH; the continuum, thermal and non-thermal. Particles and radiation: the halo problem; cosmic rays; electrons and their history. The magnetic field. Relationships to external galaxies. *Burke*

8.942 *Cosmology* (A)
Prereq.: ——
Year: G (2) 3–0–9
Cosmic ages, the Hubble law and Olbers paradoxes. Thermal backgrounds in space. The cosmological principle and its consequences: Newtonian cosmology and types of "universes"; survey of relativistic cosmology; horizons. Overview of evolution in cosmology: radiation, and element synthesis; physical models of the "early stages." Radio sources and their statistics; quasars. Variability of physical laws. (*Consent of instructor required.*) (*Alternate years*). *Morrison, Weinberg*

8.951J *Fundamentals of Radio Astronomy* (A)
(Same subject as 6.625J)
Prereq.: 6.624 or 8.05 or 8.211
Year: G (2) 3–0–9
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, spectral line radiation from H, OH, and other atoms and molecules, 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, physics of the interstellar medium, origin of cosmic rays, cosmology. Radio astronomical observations and experiments from space vehicles. (*No prior knowledge of astronomy or astrophysics required. Students who wish to do thesis work in this area are advised to take 6.624 as well as 8.951J.*)
Barrett, Staelin

8.952J *Radar Astronomy* (A)
(Same as 12.753J)
Prereq.: 8.07T, 18.08
Year: G (2) 3–0–9
Techniques of radar applied to solar-system observations. Theory of scattering of radar waves by planetary surfaces and solar corona. Delay-Doppler mapping. Sun, moon, and planet observations; inferences of coronal, atmospheric, and surface properties; determination of planetary orbits, spins, sizes, and shapes. Tests of gravitational theories. *I. I. Shapiro*

8.962 *Relativity* (A)
Prereq.: 8.312T
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.*) *Staff*

8.981 *Selected Topics in Astrophysics I* (A)
Prereq.: ——
Year: G (1) 3–0–9
Current problems in non-optical astronomy. Current investigation of astrophysical processes by means of radio, infrared, ultraviolet, X-rays, γ-rays, and extensive air showers. *Burke*

8.982 ***Selected Topics in Astrophysics II*** **(A)**
Prereq.: ——
Year: G (2) 3–0–9
Physics of the interplanetary medium. A description of: the outer corona; the interplanetary electron distribution; interaction of the solar wind with the earth's magnetic field; "collisionless" bow-shocks. Modulation of cosmic rays in the solar system. Solar flare particles. Propagation of suprathermal particles in the interplanetary medium. *Olbert*

8.991, 8.992 ***Special Problems in Astrophysics*** **(A)**
Prereq.: ——
Year: G (1 or 2) *Arr.*
Advanced problems in astrophysics with assigned reading and consultation. (*Admission by permission of instructor only.*) *Staff*

9.
Psychology

9.00 ***Introductory Psychology***
Prereq.: ——
Year: U (1, 2) 3–0–5
Survey of selected facts, principles, and theories in psychology. Historical origins, biological foundations, comparative and developmental studies, motivation, perception, learning, personality, and social processes. *Teuber*

9.001 ***Proseminar in Psychology*** **(A)**
Prereq.: 9.35, 9.40, 9.70
Year: G (1) 6–0–15

9.002 ***Proseminar in Psychology*** **(A)**
Prereq.: 9.35, 9.40, 9.70
Year: G (2) 6–0–15
Intensive survey of psychology on the graduate level, covering — in alternate terms — historical origins, biological foundations, learning, and higher processes, perception, child development, personality, and social interaction. Lectures, group discussions, and guided reading. (*Restricted to graduate students in psychology. Offered alternately in fall terms of successive years. Doctoral students may begin with either subject, but must take both.*) *Staff*

9.01 ***Physiological Psychology I***
Prereq.: 9.00
Year: U (1) 3–0–5
Biological foundations of behavior. Sensory, motor and neural mechanisms: survey of biophysical, biochemical, and morphological investigations. Evolution of the mechanisms of behavior. Anatomy and physiology of the mammalian nervous system. Techniques of studying brain structure and function, with specific illustrations and demonstrations. *Altman*

9.011 ***Seminar in Psychophysiology of Memory*** **(A)**
Prereq.: 9.001 or 9.002 or 9.01 or 9.40
Year: G (1) 3–0–6
Discussion of physiological, biochemical and structural aspects of the mnemonic process. Mechanisms of information handling in biological systems with particular emphasis upon habituation, conditioning, and similar phenomena in animals. Consideration of models and theories concerning the biological basis of memory. (*Not offered 1968–69.*) *Chorover*

9.012 ***Seminar in Physiological Psychology*** **(A)**
Prereq.: 9.001 or 9.002
Year: G (2) 3–0–6
Advanced treatment of topics in physiological psychology. (*Primarily for graduate students specializing in this field.*) *Chorover*

9.013 ***Outline of Mammalian Neuroanatomy***
Prereq.: 9.001 or 9.002
Year: G (2) 3–0–6
An elementary survey of mammalian neuroanatomy based largely on the primate brain. Emphasis more on over-all organization of the central nervous system than on cellular detail. *Nauta*

9.014 ***Practicum in Physiological Psychology*** **(A)**
Prereq.: 9.001 or 9.002 or 9.01 or 9.013
Year: G (1, 2) 2–4–3
Introduction to experimental techniques in psychophysiological research. Biophysical principles; control and measurement of electrophysiological and behavioral variables; care and treatment of laboratory animals; psychopharmacology, surgical and stereotaxic production of cortical and subcortical brain lesions, electrical and chemical brain stimulation techniques, recording and averaging of neuroelectrical activity. *Chorover, Schneider*

9.02 ***Physiological Psychology II***
Prereq.: 9.01
Year: U (2) 3–0–5
Neural correlates of behavior. Organization of the nervous system with respect to the organization of behavior. Psychophysiological studies of sensation and perception, memory and learning, feeling and emotion, motivation, thinking and communication. Disorganization of behavior: pathological processes. *Altman*

9.021 ***Brain and Behavior*** **(A)**
Prereq.: 9.001 or 9.002
Year: G (1) 3–0–6
Methods and results in neuropsychology — the correlation of neural structure with neural function (behavior). Analysis of cerebral structure in rodent, carnivore, and primate by methods drawn from macro- and microanatomy, by electrical stimulation and recording, and by chemical means. Analysis of function (behavior) proceeds by comparing effects of cerebral stimulation (or destruction) in the experimental animal, with corresponding effects of injury or disease in man. *Teuber*

9.03 ***Neural Mechanisms of Learning and Motivation***
Prereq.: 9.01
Year: U (2) 3–0–5
Consideration of the evidence for physiological mechanisms of learning and of motivated behavior (e.g. eating, drinking, sleep, maternal and reproductive behavior) derived from neuropsychological, neurophysiological and neurochemical experiments. Reports, lectures and discussion. (*Not offered 1968–69.*) *Chorover*

9.30 ***Comparative Psychology***
Prereq.: 9.00
Year: U (1) 3–0–5
Review of basic concepts and methods in the study of behavior in animals ranging from amoeba to primate. Instinctive response patterns and their specific sensory releasers. Problems of maturation and learning in the analysis of these phenomena. Survey of parallels in the evolution of sensory-neural systems and the emergence of various behavior patterns. (*Not offered 1968–69.*) *Hein*

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9.301 *Seminar in Comparative Psychology* (A)
Prereq.: 9.001 or 9.002 or 9.01 or 9.30
Year: G (2) 3–0–6
Topics for reports and discussion drawn from the following: evolution of sensory and motor systems, learning in invertebrates, animal navigation, animal communication, problems in interaction of genetic, maturational and experiential factors in the development of behavior, ethological theory, problems in the comparison of intellectual abilities within and between phyla, and similar topics. *Hein*

9.35 *Psychology of Perception*
Prereq.: 9.00
Year: U (2) 3–0–5
Critical and historical survey of phenomena revealed in study of the senses and the problems they raise for the development of theories of perception. Information drawn from anatomy, neurophysiology, psychophysics, and other relevant disciplines. *Held, Richards*

9.351 *Seminar on Sensation and Perception* (A)
Prereq.: 9.001 or 9.002 or 9.35
Year: G (2) 3–0–6
Reading, discussion, and criticism of current theory and experiments bearing on topics selected according to interests of participants. Topics may include perception of form, motion, and space; sensorimotor interaction; relevant neural processes; theoretical models, comparisons among species; and developmental approaches. *Held*

9.355 *Visual Processes* (A)
Prereq.: 6.37 or 9.001 or 9.002 or 9.35
Year: G (1) 3–0–6
Fundamental visual processes, seen as major advances in the evolution of visual systems. Integration of these processes in the human visual system. Depending upon interest of participants, topics to be emphasized: image-formation, contrast, spatial-temporal interactions, adaptation phenomena, color, binocular vision, receptive fields and physiological correlates of form and movement perception. Visual mechanisms elucidated by psychophysical and neurophysiological evidence from primitive and complex visual systems. (*Not offered 1968-69.*) *Richards*

9.361 *Electrophysiology of the Visual System*
Prereq.: 9.001
Year: G (2) 3–0–6
Survey of the electrophysiology of the mammalian visual system. Special attention given to the relationship between electrophysiological and psychophysical data. *Schiller*

9.40 *Learning*
Prereq.: 9.00
Year: U (1) 3–0–5
Theories and experimental findings on learning and memory in both humans and animals. Short-term and long-term memory for verbal and non-verbal materials, classical and instrumental conditioning, extinction, habituation, motivation and learning, discrimination learning, mathematical theories of learning and memory. *Wickelgren*

9.401 *Seminar in Learning* (A)
Prereq.: 9.001 or 9.002 or 9.40
Year: G (2) 3–0–6
Reading, discussion and criticism of selected topics. Emphasis on one or more of the following themes in a particular term: conditioning and instrumental learning, multiple response learning, problem solving and concept formation, verbal learning, memory, systematic formulations of learning phenomena, mathematical learning theories, neural mechanisms of learning. (*Not offered 1968–69.*) *Wickelgren*

9.45 *Problem Solving*
Prereq.: 9.00
Year: U (2) 3–0–5
Theories, methods, and findings in human problem solving. Analysis of some heuristic problem solving methods applied to problems taken from mathematics, logic, games, puzzles, concept attainment, and practical situations. Use of these methods by humans. Learning of new methods. Transfer of methods from one problem to another. Language and problem solving. Development of problem solving ability in children. (*Not offered 1968–69.*) *Staff*

9.491 *Seminar in Mathematical Psychology* (A)
Prereq.: 18.02
Year: G (2) 3–0–6
Reading, discussion, and criticism of selected topics. Goals of the seminar: (a) discussion of methods for mathematical formulation of psychological principles, (b) sharing of intuitive knowledge of areas of mathematics considered relevant to psychology, and (c) understanding, developing and evaluating mathematical theories of particular phenomena in perception, learning, memory, decision, and action. *Wickelgren*

9.50 *Research in Psychology*
Prereq.: 9.00 and one other subject in psychology
Year: U (1, 2) *Arr.*
Laboratory research in the areas of perception, learning and memory. Each student to carry out an original study in the area of interest to him. Survey of problems specific to research topics, design and conduct of experiments, written presentation of results. *Schiller*

9.59 *Psychology of Language and Communication*
Prereq.: 9.00 or 23.751
Year: U (1) 3–0–5
Study of psychology of language processes in light of recent advances in structural linguistics; extensive critique of learning-theoretic accounts of verbal behavior; examination of problems of language acquisition and speech perception. Methodological implications of psycholinguistic experiments and theory will be stressed. *Fodor*

9.591 *Seminar in Psychology of Language and Communication* (A)
Prereq.: 9.001 or 9.002
Year: G (2) 3–0–6
Reading, discussion, and criticism of selected topics. Emphasis on one or more of the following themes in a particular term: theories of language, speech perception, communication in sub-human species, aphasia, language acquisition, language and thought, interaction between grammatical structure and verbal performance. *Fodor*

9.595J *Philosophical Psychology* (A)
(Same subject as 21.676J)
Prereq.: ——
Year: G (2) 3–0–9
Place of psychology in the sciences. Nature of psychological explanation. Materialism and behaviorism. Problems concerning simulation of human behavior. (*Not offered 1968–69.*) *Fodor*

9.60 *Personality Structure and Development*
Prereq.: 9.00
Year: U (1) 3–0–5
Detailed study of basic personality phenomena and concepts, experimental and non-experimental methods and research findings. Phenomena discussed include: personality traits; the interrelations between motivation and memory, imagery, and thinking; anxiety, conflict, and defense; personality and beliefs; developmental changes in personality, especially in motives, modes of adaptation and morality. *Staff*

9.651 ***Cognitive Processes***
Prereq.: ——
Year: G (2) 3–0–6
Issues in the formation and exploitation of cognitive structures. Special attention to 'motor' theories of concepts, associationism, and the impact of recent psycholinguistic studies on general problems about thought and perception. (*Permission of instructor required for undergraduate students.*) *Fodor, Garrett*

9.70 ***Social Psychology***
Prereq.: 9.00
Year: U (2) 3–0–5
Examination of the basic processes by which people interact, perceive and make judgments of others, influence each other, and develop social beliefs and values, in the context of small and large groups and societies. *Staff*

9.80 ***Behavior in Groups***
Prereq.: 9.00
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. (*Not offered 1968–69.*) *Staff*

9.801 ***Social Behavior in Animals and Man*** **(A)**
Prereq.: 9.001 or 9.002
Year: G (2) 3–0–6
Comparison of forms of social interaction at several phylogenetic levels. Discussion to include those behaviors which are unique to closely related species as well as those common to members of broad taxonomic categories. (*Not offered 1968–69.*) *Hein*

9.851 ***Seminar in Social Development of Children*** **(A)**
Prereq.: ——
Year: G (2) 3–0–6
Description and comparison of children's social behavior at different stages of development. Selected topics concerned with moral development, communication and interaction, imitation and compliance, and group formation. (*Permission of the instructor required. Not offered 1968–69.*) *Staff*

9.88 ***Seminar in the Origins of Behavior***
Prereq.: 9.00
Year: U (1) 3–0–5
Interaction of innate and experiential factors in the neonatal development of learning capacities, perception, cognition, social behavior, and motor patterns. Implications of evolution, genetics, embryology, and early experience for the ontogeny of behavior. *Hein*

9.89 ***Developmental Psychology***
Prereq.: 9.00
Year: U (2) 3–0–5
Survey of major issues, problems, and theories of ontogenetic development. Developmental aspects of sensorimotor coordination, perception, learning and personality. *Schiller*

9.891 ***Seminar in Developmental Psychology*** **(A)**
Prereq.: 9.001 or 9.002
Year: G (2) 3–0–6
Advanced treatment of topics in developmental psychology. (*Not offered 1968–69.*) *Hein*

9.92 ***Advanced Psychology Seminar***
Prereq.: 9.00 and any two subjects in psychology
Year: U (2) *Arr.*
Critical survey of contemporary problems in experimental psychology. *Staff*

9.921 ***Research in Psychology*** **(A)**
Prereq.: 9.001 or 9.002
Year: G (1) *Arr.*
Guided research under the sponsorship of individual members of the faculty. Ordinarily restricted to candidates for the doctor's degree in psychology. *Staff*

9.922 ***Research in Psychology*** **(A)**
Prereq.: 9.001 or 9.002
Year: G (2) *Arr.*
Guided research under the sponsorship of individual members of the faculty. Ordinarily restricted to candidates for the doctor's degree in psychology. *Staff*

10.
Chemical Engineering

10.12 ***Staged Cascades in Chemical Processing***
Prereq.: ——
Year: U (1) 3–3–6
Cascade theory of staged separations processes such as solvent extraction, distillation, absorption, and gaseous diffusion. Numerical iteration techniques and computer methods. Concepts of reflux. Ideal cascades. Finite-difference methods for linear systems. Graphical methods of analysis. Computer techniques for multicomponent distillation. Coupled cascade systems and chemical reactor-cascade system coupling. Design and optimization of such systems. *Brian*

10.13T ***Chemical Engineering Thermodynamics***
Prereq.: 5.60, *18.034*
Year: U (2) 4–0–8
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, 2) *Arr.*
Work done in conjunction with the S.B. thesis. Written and oral reports on literature survey and experimental work. Normally consists of three units in the fall term plus one unit in the spring term. *L. B. Evans*

10.18 ***Industrial Chemistry***
Prereq.: 5.60; 10.301 or 10.311
Year: U (2) 3–0–6
Industrial chemical processes 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. *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.

10.21 ***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. Presentation of subject matter similar in content to 10.211 at a level commensurate with background of seniors majoring in chemical engineering. Emphasis on development of an approach based upon examination of phenomena, for solving problems in chemical processing. *Deibert*

10.211 ***Structures and Properties of Matter*** **(A)**
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
Atomic and molecular interactions and their importance in determining physical and chemical properties of matter. Properties of gases, liquids, and crystalline solids; rheologic and elastic phenomena in amorphous solids with emphasis on synthetic and natural polymeric substances. Techniques for characterizing molecular structure and for predicting properties of solids, liquids, and gases. *Deibert*

10.24 ***Chemical Engineering Instrumentation Laboratory***
Prereq.: 5.60
Year: U (1, 2) 1–3–1
Combination of lectures, demonstrations, and laboratory exercises outlining principles and range of applicability of a number of instrumentational methods currently important in chemical engineering. Opportunities to work with specific instruments in association with research workers. Emphasis on gas chromatography, infrared spectroscopy, and potentiometric measurements. Study of some of the following topics: flame photometry, ultra-violet and visible spectrophotometry, hot-wire anemometry, viscometry, microscopy, transient temperature measurements, pyrometry, pH measurements, and radiation counting techniques. ——

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*

10.26 ***Industrial Chemistry Laboratory***
Prereq.: 5.41, 10.13T
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. *Fleming*

10.27 ***Chemical Engineering Laboratory***
Prereq.: 10.301
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. *Fleming*

10.301 ***Modes of Heat and Mass Transfer***
Prereq.: 10.13T
Year: U (1) 4–0–6
Diffusive transport of heat or mass in stationary media; additivity of resistances concept and transient analysis. Radiative transport of energy. Convective transport. Chemical engineering design of heat and mass exchangers. *K. A. Smith*

10.302 ***Fluid Mechanics and Transport Processes***
Prereq.: 10.301
Year: U (2) 4–0–6
Introduction to fluid mechanics. Dynamics of fluids in motion; laminar and turbulent flow; Bernoulli's equation; friction in conduits, boundary layer theory; Navier-Stokes equations. Convective transport analysis. The analogies, boundary layers, condensation, natural convection. *K. A. Smith*

10.311 ***Continuum Mechanics***
Prereq.: 10.301
Year: U (2) 4–0–6
A sound foundation for extensive work. Kinematics of continua; forces and stresses in continua; fluid statics; flow of an ideal fluid; rheology of real fluids; simple laminar flows. *K. A. Smith*

10.312 ***Transport Phenomena***
Prereq.: 10.311
Year: U (1) 4–0–6
Convective heat and mass transfer. Boundary layer flows, turbulence, the analogies, flow past bluff bodies, condensation, natural convection. *K. A. Smith*

10.32 ***Chemical Engineering***
Prereq.: 10.301
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. *Virk*

10.33 ***Analytical Treatment of Chemical Engineering Processes*** **(A)**
Prereq.: 10.32, 18.034
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. *L. B. Evans*

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 7094 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 7094. (*Limited to ten students. Permission of instructor required.*) *Brian*

10.35 ***Dynamics and Control of Chemical Engineering Processes*** **(A)**
Prereq.: 10.32, 18.06
Year: G (1) 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. Optimal control theory. Use of analog and digital simulation techniques. Design and analysis of conventional and computer control systems. *L. B. Evans*

10.361 *Process Design*
Prereq.: 10.301
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*

10.362 *Process Design*
Prereq.: 10.301
Year: U (2) 3–0–6
Same as 10.361, but with new case studies. May be taken by students who have credit for 10.361. *G. C. Williams*

10.37 *Chemical Kinetics and Reactor Design*
Prereq.: 5.62, *10.301*
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. *G. C. Williams*

10.38 *Analysis and Simulation of Chemical Processing Systems* (A)
Prereq.: 10.32, 18.034
Year: G (2) 2–2–4
Introduction to techniques for computer-aided analysis of chemical processing systems. Development of mathematical models to describe dynamic and steady-state process behavior. Representation of the structure of complex, interconnected chemical processes with arbitrary recycle stream. Numerical methods for solving resulting systems of non-linear differential and algebraic equations. Analog computation. Use of one or more special digital simulation languages. Application of various mathematical optimization techniques. Survey of recent developments in comprehensive problem-oriented computing systems to assist in chemical process design. Training in computer programming in special class sessions. *L. B. Evans*

ENGINEERING OPERATIONS

10.40 *Chemical Engineering Thermodynamics* (A)
Prereq.: 5.62, 10.13T
Year: G (1, 2) 4–0–8
First and Second Laws for open and closed systems. Thermodynamic properties of pure materials and mixtures. Criteria of equilibrium and applicability to homogeneous and complex heterogeneous systems including the effect of chemical reactions. Some discussion of the correlation and estimation of thermodynamic properties. *Reid*

10.41 *Distillation* (A)
Prereq.: 10.13T, 10.32
Year: G (1 or 2) 3–0–6
Basic principles of distillation as applied to binary and multicomponent mixtures. Vapor-liquid equilibria of real solutions at low and high pressures. General principles of staged contacting; cascade configurations. Thermodynamic considerations in distillation; energy utilization; Second Law implications; multicomponent distillation. Distillation of systems of limited miscibility; azeotropic and extractive distillation. Batch distillation; vacuum distillation. Multicolumn distillation systems. Distillation plate efficiencies. Plate design considerations. *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 multicomponent mixtures such as those encountered in typical petroleum refinery operations. Simultaneous absorption and chemical reaction. Graphical methods. Basic principles of extraction by liquids, solvent recovery by absorption and the leaching of various solids. *Vivian*

10.47 *Ion Exchange* (A)
Prereq.: 5.62, 10.32
Year: G (2) 2–0–4
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.: 10.301
Year: G (2) 3–0–6
Application of fundamentals of conduction, radiation, and convection of heat to industrial problems. Numerical methods for complex problems in transient and steady conduction. Analogies between transfer of heat and momentum. Design problems, including economic balance between cost of heat-transfer surface and power. (*Not offered 1968–69.*) *Sarofim*

10.52 *Mechanics of Fluids* (A)
Prereq.: 10.32
Year: G (1) 3–0–6
Development of basic relationships governing fluid flow with emphasis on continuity, linear momentum, and angular momentum equations. Flow of incompressible fluids employing the continuum approach. Cartesian tensor and dyadic notations in the context of describing the state of stress and rate of strain. Perfect fluids, simple laminar motions, creeping motions, laminar boundary layers, concepts of turbulence. Prior knowledge of vector calculus required. *K. A. Smith*

10.53 *Chemical Engineering Design* (A)
Prereq.: 10.301
Year: G (1, 2) 3–0–6
Same as 10.361 but with the case study level compatible for graduate students. *Sherwood*

10.56 *Chemical Engineering in Medicine* (A)
Prereq.: 5.62, 10.301
Year: G (2) 2–0–4
Seminar with oral presentations by members on topics of current interest involving broad applications of chemical engineering to medical problems. Visits to local hospitals and discussions with physicians, surgeons, and life scientists on problems of mutual interest. *Merrill*

10.59 *Properties of Gases, Liquids, and Solids* (A)
Prereq.: 5.62, 5.63
Year: G (2) 3–0–6
Consideration of intermolecular forces from both empirical and theoretical points of view. Treatment of dipole, induced polarization, and London-type forces. Subsequent application of these intermolecular forces to the problem of predicting equilibrium and transport properties of gases. Brief discussion of some of the modern theories of liquid and solid structure, with illustration by real systems. *Reid*

(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.

APPLIED CHEMISTRY

10.60 *Catalysis*
Prereq.: 5.62
Year: U (1) 3–0–6
Relationships of activity and selectivity to physical and chemical properties of a solid catalyst. Components and preparation of catalysts. Physical adsorption, chemisorption. Physical characterization of catalysts; surface area, pore size distribution. Examination of catalyst structures and surfaces by such methods as infrared absorption, low-energy electron diffraction, electrical conductivity, and magnetic measurements. Kinetic models and correlation of rate data. Electronic factors in catalysis; geometrical factors; concept of the unstable intermediate. Acid catalysts. Role of diffusion in catalysis. Case studies of several industrial catalysts and associated catalytic processes. *Modell*

10.602 *Catalysis* (A)
Prereq.: 5.62
Year: G (1) 3–0–6
Same as 10.60 but with a level of study appropriate for graduate students. *Modell*

10.61 *Physics and Chemistry of Surfaces* (A)
Prereq.: 5.62
Year: G (1) 3–0–6
Thermodynamic, kinetic, and chemical factors underlying surface and interfacial phenomena. Intermolecular forces, orientation at interfaces and the origins of surface tension. Capillarity and the effects of surface curvature on bulk phase properties. Thermodynamics of adsorption at interfaces; the Gibbs adsorption isotherm. Electrical phenomena at interfaces: origins of surface potential, structure of the diffuse double layer, electrokinetic phenomena. Surface-active agents, contact angles, spreading, and wetting phenomena. Properties of colloidal electrolytes, micelles, solubilization phenomena, monolayers. Correlation of these fundamentals of surface and interfacial phenomena with important industrial applications as: emulsions, foams, flotation, detergency, adhesion, and lubrication. Survey of some important surface phenomena in biological systems. *A. S. Hoffman*

10.62 *Advanced Thermodynamics* (A)
Prereq.: 10.40
Year: G (2) 2–0–4
Fundamental equations in Gibbs coordinates. Legendre transforms. Discussion of Gibbs equilibrium criteria and applicability to heterogeneous systems, to systems in body force fields, and to systems involving large surface areas. Derivation and discussion of stability criteria. Introduction and application of entropy production and Onsager's reciprocal relations to simple irreversible thermodynamic problems. *Reid*

10.631 *Surface and Colloid Chemistry*
Prereq.: 5.60
Year: U (1) 2–0–4
Consideration of selected phenomena and processes relevant to chemical engineering characterized by large interfacial area relative to phase volume. Surface chemistry and physics: interfacial tension and pressure, contact angle, capillarity, wetting, surface active agents and monolayers. Colloid particles: electrical double layer theory, preparative methods, flocculation, and sedimentation. Control of rate processes at a phase interface, including nucleation and crystallization. *A. S. Hoffman*

10.64 *Structure and Properties of Polymers* (A)
Prereq.: 5.42, 5.60
Year: G (2) 3–0–6
Relationship of molecular structure and composition of organic high polymers to their bulk physical properties. Kinetic theory of rubber elasticity, glass transition behavior, viscoelastic theory, melt rheology, crystallinity in polymers. Effects of orientation, crosslinking, plasticization, copolymerization and presence of fillers on the properties of plastics, elastomers, fibers, films, and foams. Physical properties including mechanical (dynamic and transient), electrical, optical, gas transport properties. *A. S. Hoffman*

10.641J *Polymer Materials Science*
(Same subject as 2.901J)
Prereq.: 5.01
Year: U (1) 3–0–9
Principles of macromolecular structure, their relation to properties of polymers and application to the design of engineering materials. Statistics of macromolecules and experimental determination of their sizes and shapes. Model structures: helices, extended chains, folded chains, and random coils. Theories of rubber elasticity, glass transitions and crystalline melting transitions. Melt rheology and extrusion theory. Survey of engineering properties of rubbers, proteins, glasses, plastics, and fibers. *A. S. Hoffman, Yannas*

10.648 *Synthesis and Properties of Polymeric Materials*
Prereq.: 5.41; 5.62 or 5.63
Year: U (2) 2–0–4
Principles of the synthesis, dilute solution properties and bulk properties of macromolecules are covered. The chemistry of polymerization mechanisms; conformational statistics of long chains, solution thermodynamics, viscosity of polymer solutions, rubber elasticity, viscoelasticity of bulk solid and molten polymers, glass transitions and crystalline structure of single crystals, bulk undrawn and drawn polymeric materials. *A. S. Hoffman*

10.65 *Applied Chemical Kinetics* (A)
Prereq.: 5.62, 10.37
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. Design of batch, plug-flow, and continuous stirred-tank reactors for homogeneous reactions. Residence-time distributions and "mixedness." Role of mass transfer in heterogeneous reactions. Choice and design of reactors for heterogeneous reactions. Emphasis on interpretation of experimental data and application to kinetic and reactor design problems. *Satterfield*

10.66 *Surface Science and Engineering* (A)
Prereq.: 5.62
Year: G (2) 3–0–6
Molecular constitution of interfaces, origin of surface tension; relation to intermolecular forces. Capillarity and surface thermodynamics; monolayer formation, properties, and degree of ordering. Description of supraordered microstructures and their formative processes: flocculation, nucleation and crystal growth, coacervation and gelation. Sorption in — and transport through — such structures: Langmuir, BET, Polanyi, Zimm-Lundberg treatments; elementary consideration of membrane transport phenomena and flow in microporous media.

10.68 *Physical Chemistry of Polymers* (A)
Prereq.: 5.42, 5.62
Year: G (1) 3–0–6
Principal emphasis on linear, random-coiling, non-electrolytic polymers. Conformation properties of the isolated random-coiling macromolecule, including the radius of gyration, segment density distribution, effective diameter in the computation of excluded volume and entropy elasticity. The definition of the *dilute* polymer solution based on volume fraction of "free" solvent external to random coils. The statistical thermody-

namics of polymer solutions, derived (following Flory) for the *dilute* and for the *concentrated* solution. Applications to osmotic phenomena and to phase equilibria including fractionation. Thermodynamic and conformational properties deduced from light scattering of polymer solutions. Extension of thermodynamic analysis to the theory of the intrinsic viscosity of polymer solutions. Special topics include: (a) non-Newtonian viscosity of polymer solutions (including gradient dependence of intrinsic viscosity); (b) response of dilute polymer solutions in turbulent flows (including the Tom's effect); (c) thermodynamic and hydrodynamic properties of certain biological polymers, including the hyaluronates. *Merrill*

10.69 *Polymerization Processes* (A)
Prereq.: 5.42, 5.62
Year: G (2) 3–0–6
Synthesis of polymers with emphasis on interrelationships of reaction kinetics, chemical equilibria, fluid mechanics, heat transfer, and mass transfer. Specific topics include condensation polymerization; classical free radical polymerization in solution and in bulk; high-pressure radical polymerization of ethylene; emulsion polymerization and bead polymerization; cationic polymerization of isobutylene; anionic polymerization; Ziegler-Natta and related heterogeneous, stereoregulating polymerizations, various processes for generating cross-linked polymers or elastomers ("vulcanization" of elastomers, epoxy resin reactions, isocyanate-urethane reactions, maleic polyester-styrene reactions), and processes for chemical conversion of side groups on previously synthesized polymers (acetylation of cellulose, deacetylation of polyvinyl acetate, sulfonation or quaternization of polystyrene). *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 *Seminar in High Temperature Phenomena* (A)
Prereq.: ——
Year: G (2) 2–0–4
Oral presentations by members and invited guests and class discussion on topics in high-temperature generation, kinetics, thermodynamics of high-temperature processes, measurement of high temperatures, and rapid quenching. Special emphasis on problems in combustion and in the production of chemicals. *Baddour, Hottel*

10.74 *Radiative Transfer* (A)
Prereq.: 10.301
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

10.80 *School of Chemical Engineering Practice — Bound Brook Station*
Prereq.: 10.32
Year: U (2) 0–18–0
For seniors during the second period of the academic year. ——

10.81 *School of Chemical Engineering Practice — Oak Ridge Station*
Prereq.: 10.32
Year: U (2) 0–18–0
For seniors during the second period of the academic year. ——

10.82 *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. ——

10.83 *School of Chemical Engineering Practice — Bound Brook Station* (A)
Prereq.: 10.82
Year: G (1 or 2) 0–12–0
Continuation of 10.82. ——

10.84 *School of Chemical Engineering Practice — Bound Brook Station* (A)
Prereq.: 10.83
Year: G (1 or 2) 0–12–0
Continuation of 10.83. ——

10.85 *School of Chemical Engineering Practice — Bound Brook Station* (A)
Prereq.: 10.84
Year: G (1 or 2) 0–12–0
Continuation of 10.84. ——

10.86 *School of Chemical Engineering Practice — Oak Ridge Station* (A)
Prereq.: 10.32
Year: G (1 or 2) 0–12–0
Conducted at the Oak Ridge, Tennessee, Station located at the Oak Ridge National Laboratory of the Atomic Energy Commission, operated by Union Carbide Company, Nuclear Division. Work under direction of Institute faculty residing at Oak Ridge with emphasis on the application of engineering principles to the solution of research and development problems arising from the programs of the Oak Ridge National Laboratory. *Application should be made three to four months in advance to allow ample time for routine entry procedures.* ——

10.87 *School of Chemical Engineering Practice — Oak Ridge Station* (A)
Prereq.: 10.86
Year: G (1 or 2) 0–12–0
Continuation of 10.86. ——

10.88 *School of Chemical Engineering Practice — Oak Ridge Station* (A)
Prereq: 10.87
Year: G (1 or 2) 0–12–0
Continuation of 10.87. ——

(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.

10.89 ***School of Chemical Engineering Practice — Oak Ridge Station*** **(A)**
Prereq: 10.88
Year: G (1 or 2) 0–12–0
Continuation of 10.88. ——

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. *Meissner*

10.991 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: ——
Year: G (1) 2–0–4

10.992 ***Seminar in Chemical Engineering*** **(A)**
Prereq.: ——
Year: G (2) 2–0–4
For students working on doctoral theses. *Gilliland*

11.
City and Regional Planning

11.001 ***Representation***
Prereq.: ——
Year: G (1) 1–3–2
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. *Staff*

11.01T ***Community Planning Design***
Prereq.: 11.001, 11.11
Year: U (1) *Arr.*
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. *Staff*

11.02 ***City and Regional Planning*** **(A)**
Prereq.: 11.01T
Year: G (2) *Arr.*
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*

11.03 ***Problems in City Planning*** **(A)**
Prereq.: 11.02
Year: G (2) *Arr.*
Advanced problems in city planning, including pioneering studies and studies in specialized areas. *Staff*

11.05T ***Collaborative Design*** **(A)**
Prereq : 11.02
Year: G (1) *Arr.*
Project work on design problems which will benefit from collaboration between architects and city planners or between these groups and other disciplines. *Staff*

11.06 ***Problems in Urban Design*** **(A)**
Prereq.: 11.02, 11.05T
Year: G (2) *Arr.*
Advanced problems in planning for the visual form of the environment at the scale of cities or regions. *Staff*

11.08T ***Problems in Regional Planning*** **(A)**
Prereq : 11.45
Year: G (1) *Arr.*
Advanced problems in spatial planning and programming development at the regional scale: resource regions, depressed areas, and intermetropolitan zones in the United States. (*Not offered 1968–69.*) *Staff*

11.10 ***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. (*Restricted to Course* XI *students.*) *Staff*

11.11 ***Components of the Urban Environment***
Prereq.: ——
Year: U (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*

11.12 ***City Planning Techniques***
Prereq.: 11.11
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*

11.15 ***Site Planning***
Prereq.: ——
Year: U (2) 1–2–5
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. (*Limited enrollment.*) ——

11.20 ***Models and the Metropolis*** **(A)**
Prereq.: 11.60
Year: G (1) 2–0–6
Examination, in detail, of current tries at reducing the metropolis to simple systematics through mathematical models describing spatial patterns — e.g., of population, of economic activity, or of circulation flows. *Fleisher*

11.21 *The Urban Transportation Problem* (A)
Prereq.: 11.11, 11.60
Year: G (2) 2–0–6
Seminar on the conditions of transportation in American and foreign cities; nature of the urban transportation problem as it is now and what it may become; its relevance to the form and structure of the city. Critical scrutiny of current research with particular emphasis on methods, old and new. *Fleisher*

11.22 *Transportation and Urban Form* (A)
Prereq.: 11.11, 11.60
Year: G (1) *Arr.*
Seminar on the relations between transportation in the city and its form, structure, and quality; alternate designs for metropolitan transportation systems and the possibilities of innovation in organization and technology. *Fleisher*

11.25 *Housing Problems*
Prereq.: 11.11 or 11.60 or 14.01
Year: G (1) *Arr.*
The meaning and scope of housing problems. The market and social system for producing housing; evaluation of economic, social, design, administrative, and political problems. The broadening perspective of housing policy in the United States and other countries. Extensive readings and a paper required. *Keyes*

11.31 *Urban Landscape* (A)
Prereq.: 4.121 or 11.11
Year: G (2) 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. (*Not offered 1968–69.*) *Lynch*

11.32 *City Design* (A)
Prereq.: 11.31
Year: G (1) 2–0–6
Seminar on principles and techniques for the comprehensive design of the city environment, with special attention to its perceptual form; the relation between city form and community objectives; the visual plan as part of the total planning process. (*Limited enrollment. Not offered 1968–69.*) *Lynch*

11.33 *Advanced City Design* (A)
Prereq.: 11.31
Year: G (1) 2–0–6
Criteria and methods for the design of the city environment, focusing on sensory qualities, communication, elements, systems, change and design for various population groups. Techniques of notation and simulation, methods of implementation and control. Case studies and design exercises. (*Not offered 1968–69.*) ——

11.34 *Psychology of the Environment*
Prereq.: ——
Year: G (1) *Arr.*
Applications to environmental design of theories, experimental methods, and findings in psychology. Discussion of the following topics, both from the viewpoint of current psychology and in reference to environmental design: perception, attention, memory, learning, thinking, interpersonal attitudes and behavior, needs and values. (*Open to advanced undergraduates and to graduate students.*) *M. C. Potter*

11.35 *Psychological Functions of Environmental Form* (A)
Prereq.: 11.34
Year: G (2) 2–0–6
Advanced analysis of topics of special interest to individual students, emphasizing experimental approaches. Organization and character of the environment as significant variables in the psychological processes basic to effective human functioning. Attention to various scales of environment, from a single room to an urbanized region, but focusing on the implications for city design. *Carr, M. C. Potter*

11.45 *Metropolitan and Regional Planning in Developing Countries* (A)
Prereq.: 11.60
Year: G (2) *Arr.*
Problems of cities and regions in developing countries in relation to economic and social development policy. Extended readings and workshop problems. *Rodwin*

11.46 *Urban Settlement, Squatters, and Social Change* (A)
Prereq.: 11.25, 11.50 or 11.60
Year: G (1) *Arr.*
Lectures and seminars on the urban accommodations of the low-income sectors in urbanizing countries and the formation of squatter settlements. Examination of the principal social, economic and physical determinants of housing and settlement forms and development procedures in the context of a transitional economy. *J. Turner*

11.50 *Urban Social Structure and Process*
Prereq.: ——
Year: U (1) 2–0–6
The city as a social system, including social subsystems, from the perspective of continuity of social structure across generations. Study of the conflict relations among various segments of the urban population — race, religion, and so on — for their implications; examination of segregation and its effects. The problems of child-raising in a modern city — the family and the educational system viewed from this perspective. The impact of social and technological change upon urban social systems. The physical and environmental characteristics of a city as outputs of social systems as well as constraints upon behavior. ——

11.51 *Seminar on Urban Social Structure*
Prereq.: 11.50
Year: G (2) 2–0–6
Readings and discussion of recent theoretical developments on urban social structure; compatibility of utopian social patterns and systems with rules of social structure based on current social science research; transition of societies, as from agrarian to industrial. Mathematical background helpful. (*Not offered 1968–69.*) ——

11.52 *Seminar on Simulation of Large-Scale Social Systems* (A)
Prereq.: 11.90
Year: G (2) 2–0–6
Considerations of mathematical design, computer technique, and data sources that facilitate the construction of simulation models of large-scale social systems. Attention to national models and models of metropolitan regions. Social mobility, migration, and fertility will be considered as components of large-scale social systems. (*Not offered 1968–69.*) ——

11.53 *Mathematical Sociology* (A)
Prereq.: 11.90
Year: G (2) *Arr.*
Review and critique of recent mathematical models in sociology. Intended for students with previous training in mathematics and in social sciences. (*Not offered 1968–69.*) ——

(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.

11.55 *Urban Planning and Social Policy* (A)
Prereq.: 11.01T, 11.50
Year: G (1) *Arr.*
Interdisciplinary approaches to planning for urban problems, drawing on methods of (a) city and regional planning, and (b) social planning. Definition of urban problems as seen in the framework of each discipline, and identification of promising areas for collaborative planning. Focus on developing and evaluating techniques for dealing with selected problems in relocation planning, manpower training, and urban renewal. *(Offered jointly with Florence Heller Graduate School for Advanced Studies in Social Welfare, Brandeis University.)* *Frieden*

11.56 *Urban Social Policy Seminar* (A)
Prereq.: 11.01T, 11.50
Year: G (2) *Arr.*
Development of planning methods for dealing with selected areas of urban social policy; exploration of current social issues as they relate to city and regional planning, such as race and housing, relocation, anti-poverty programs, and health and welfare services. Focus, varying from year to year, initially on health services and facilities. *(Offered jointly with Florence Heller Graduate School for Advanced Studies in Social Welfare, Brandeis University; and Department of City and Regional Planning, Harvard University.)* *Frieden*

11.57 *Planning and Poverty* (A)
Prereq.: 11.50
Year: G (1) 2–0–6
The culture of poverty, its social and economic manifestations; programs for the amelioration of the poverty problem; interactions among programs for social, economic, and environmental change; case studies and readings. *Peattie*

11.575 *Social Aspects of Development* (A)
Prereq.: 11.25, 11.50 or 11.57
Year: G (2) 2–0–6
Seminar discussion of the social and cultural aspects of economic development: urbanization, changing systems of social stratification, urban family structure, and the concept of a "culture of poverty." Treatment of the themes so as to show a sense of the social and cultural transformations implied by economic development and how "social problems" may be thought about in terms of their technical, economic, and institutional parameters. *Peattie*

11.58J *Seminar on Metropolitan Development Policy* (A)
(Same subject as 17.215J)
Prereq.: 11.01T, 11.50
Year: G (2) *Arr.*
Interdisciplinary seminar on policy issues posed by metropolitan development. Evaluation of suburban growth and its impact on the governmental system, public services, and emerging social and economic characteristics of central cities and suburbs. Consideration through research, field work, and case studies, of public action for guiding metropolitan development, including intergovernmental relations and national urban policy. *Frieden, Altshuler*

11.59 *Deliberate Social Change in the Cities* (A)
Prereq.: 11.11 or 11.25 or 11.57
Year: G (2) *Arr.*
Study of theories and strategies of social and institutional change in urban settings, case studies in the formation of community corporations, urban development corporations, the advocate planning role, the neighborhood health center as a means to social change, low-income housing. Examination of relationships between social and technological change. Work toward a theory of deliberate social change, taking account of the stance and role of the change agent, the institutional forms involved, and the special areas of concern. *Schon*

11.60 *City Structure and Economic Development*
Prereq.: ——
Year: U (1) 2–0–6
Economic, social, and technological factors which affect the functions and physical environment of the city and region; analytical techniques for evaluating urban, intra-metropolitan, and interregional characteristics; an evaluation of the issues posed by national policy for urban and regional development. ——

11.62 *Urban Development Patterns and Economic Growth* (A)
Prereq.: 11.60
Year: G (2) 2–0–6
Designed for the urban planner and urban economist: background on our U. S. urban economy, the characteristics and significance of the postwar growth, the perspectives and potential in the next generation, and the expanding role of urban infrastructure in the optimization of resource use for the economy as a whole. Extensive readings, preparation of a quantitative analytical paper covering some phase of urban growth analysis and projection. *(Not offered 1968–69.)* *Ganz*

11.65T *Real Estate Economics*
Prereq.: 14.01
Year: G (1) 2–0–6
Social, political, industrial and economic factors affecting the location, construction, financing and marketing of real estate and buildings — with emphasis on the relationships between the interests of the planner, the architect and the developer-investor. *Weisberg*

11.66J *Urban Economics: Positive Analysis I* (A)
(Same subject as 14.572J)
Prereq.: 14.03 or 14.04T
Year: G (2) 3–0–6
Economic analysis of urban areas in their regional setting, organized around the sources, characteristics, and implications of spatial concentration of economic activities. Consideration of both market and governmental forces. Location theory; spatial competition; general equilibrium models of interregional economic activity with emphasis on input-output and linear programming models; interregional transmission of economic fluctuations; metropolitan growth and development. Explicit attention to spatial factors affecting the demand for transportation services. *Paelinck*

11.67J *Urban Economics: Positive Analysis II* (A)
(Same subject as 14.573J)
Prereq.: 11.66J or 14.572J
Year: G (1) 3–0–6
Continuation of 11.66J. The land use market and the spatial structure of the metropolitan community. Models of the metropolis. The housing market; demand and supply, growth, aging and urban renewal. The economics of race in the metropolitan area, the Model Cities Program. The urban transportation system and its problems. In each of these topics, emphasis on the resource allocation process, its efficiency, and sources of suboptimality. *Rothenberg*

11.68J *Urban Economics: Positive and Normative Analysis III* (A)
(Same subject as 14.574J)
Prereq.: 11.67J or 14.573J
Year: G (2) 3–0–6
Continuation of 11.67J. The nature and problems of government decision making in metropolitan areas. Urban-suburban relations: market and governmental

interactions. Optimal and suboptimal government. Welfare economics and the normative theory of local public policy. Applied normative analysis: criteria for public expenditures; cost-benefit analysis. Examination of public policy issues in current urban problems: poverty, race, the spatial form of the city, optimal land use patterns, growth and renewal. *Rothenberg*

11.70 *Law of Land Use* (A)
Prereq.: 11.12
Year: G (1) 2–0–6
The basis in constitutional, common, and statute law and decisions of regulation or taking of private property to accomplish public purposes; the balance between public and private interests; zoning, urban renewal, and other plan implementation devices; study of leading court cases. ——

11.75 *Metropolitan Planning Administration* (A)
Prereq.: 11.12
Year: G (2) 2–0–4
Methods and practices of planning and implementation; organization of planning agencies, relationships to government and private operations; techniques of administration. (*Not offered 1968–69.*) ——

11.80 *Theory of the Planning Process* (A)
Prereq.: 11.12
Year: G (1) *Arr.*
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.*) *Rodwin*

11.81 *Theory of City Form* (A)
Prereq.: 11.12
Year: G (2) 2–0–6
Seminar on the analysis of the functioning, effects, and implications of the general form of the urban physical environment. Effect of this form on basic human objectives. (*Limited enrollment.*) ——

11.90 *Methods of Research in City Planning*
Prereq.: 11.11
Year: U (2) 2–0–6
Lectures and seminars on the treatment, organization, and validity of some data used by city planners; the use and limitations of some linear and non-linear analyses of activities in the city; urban models and simulations. *Staff*

11.911 *Introduction to Information Processing*
Prereq.: ——
Year: G (1) 2–0–4
Basic principles of digital computers and programming languages. Practice in writing programs in algebraic and problem-oriented languages. Introduction to describing planners' problems as computational processes and programming a digital computer to solve them. Intended for students with no previous contact with computers. *McMains*

11.912 *Computer Systems Seminar* (A)
Prereq.: 11.20, 11.911
Year: G (2) *Arr.*
Advanced discussion of existing computer systems and current research on new systems that help the planner to communicate with the machine. Discussion of the computer realization of mathematical models. Opportunity for the student to do individual research in the area of planning models or planner-machine communication. *Fleisher, McMains*

11.92 *City Planning Research* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Selected topics in city planning. Supervised study, with conferences, readings, and reports. No lectures. *Staff*

11.93 *Regional Planning Research* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Selected topics in regional planning. Supervised study with conferences, readings, and reports. No lectures. *Staff*

11.95 *Preparation for Thesis* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
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. (*Restricted to doctoral candidates.*) *Staff*

12.
Geology and Geophysics

12.01 *Special Problems*
Prereq.: ——
Year: U (1 or 2) *Arr.*
For students desiring reading or special laboratory or field work on geological or geophysical problems in sedimentology, petroleum geology, economic geology, paleontology, exploration geophysics, space physics, and other fields. *Staff*

12.03 *Geology III*
Prereq.: 12.232T
Year: U (2) 3–4–5
Evolution of plants and animals. Principles and methods of stratigraphy. Rock weathering, production of sedimentary materials. Sediment erosion, transportation, and deposition. Survey of modern depositional environments. Petrology of major sedimentary rock types: classification, composition, primary textures and structures. Lithification and diagenesis. Geologic occurrence of metallic and non-metallic mineral deposits. Laboratory work on fossils, sediments, sedimentary rocks and processes. Two Saturday field trips to examine local sediments and sedimentary rocks. *Southard*

12.09 *Analysis of Geological Materials*
Prereq.: 5.01, 8.03T, 12.231
Year: U (2) 2–0–2
Introduction to instrumental techniques for the analysis of geologic materials. Topics on applications of X-ray spectrometry, X-ray diffraction, neutron activation analysis, atomic absorption spectrophotometry, mass spectrometry, optical emission spectrometry, electron-probe microanalysis, and chromatography. One of these techniques in detail and the others in outline form. (*Enrollment limited to 12 students; admission only by permission of the instructor.*) *F. A. Frey*

(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.

12.10 *Seminar in Geology and Geochemistry* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Problems of current interest in geology or geochemistry. Subject matter varying from term to term. *Staff*

12.201 *Earth Science*
Prereq.: ——
Year: U (1) 2–1–3
Lectures on the origin, history, and evolution of the earth. Emphasis on geological, geochemical, and geophysical aspects of earth science. Topics include: geochronology; isotope geology; distribution and relative abundance of elements; topics in physical and historical geology; origin of land forms; mineral, rock, and fossil identification. Several field trips with at least one trip required of all students. *Pinson*

12.202 *Astronomy*
Prereq.: ——
Year: U (2) 2–0–4
Introduction to the principles and methods of modern astronomy. Observational facilities, including two telescopes of 12- and 24-inch apertures, of the Whitin Observatory at Wellesley College available on Friday nights. One or more opportunities for each student to visit the observatory on clear nights. Motz and Duveen, *Essentials of Astronomy.* *Pinson*

12.203 *Workshop in Astronomy*
Prereq.: 12.202
Year: U (2) 0–6–0
Workshop in observational astronomy conducted every Friday night at Whitin Observatory, Wellesley College. Instruction in operating the telescopes, taking celestial photographs, using a spectrohelioscope; exercises using variable star data, and exercises with stellar spectra. *Pinson*

12.211 *Planetology*
Prereq.: 5.01, 8.01, 18.02
Year: U (1) 2–0–4
Selected topics in planetary science. Transformations of celestial coordinate systems; nature of the lunar surface; origin, evolution and retention of planetary atmospheres; distributions and relative abundances of the elements and nuclides; the new science of astrogeology; meteoritics with special emphasis on isotope studies; tektites and the cratering process; cosmic dust, meteors and comets; theories of origin of the solar system. (*Alternate years.*) *Pinson*

12.223 *Crystallography*
Prereq.: ——
Year: U (1) 2–2–2
Introduction to the nature of crystalline matter. Patterns of atoms in crystals and how they are investigated. Crystal symmetry; point groups, crystal forms, space groups. Use of X-ray diffraction in the study of crystals. The rotating-crystal, Weissenberg, and precession methods. Modern methods of determining the arrangements of atoms in the cell, Fourier synthesis, the Patterson function, and refinement. Buerger, *Elementary Crystallography;* Buerger, *Contemporary Crystallography.* (*Alternate years.*) *Buerger*

12.224 *Theoretical Mineralogy*
Prereq.: 12.223
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. (*Alternate years. Not offered 1968–69.*) *Buerger*

12.231 *Geology I*
Prereq.: 5.01, 8.02
Year: U (1) 3–4–5
Introduction to the elements of geology: structure of the crust and mantle; composition and evolution of the common crystalline rocks; mineralogy with emphasis on rock-forming silicates; construction and interpretation of geologic maps; structure of typical continental and oceanic areas. Laboratory work on rocks and minerals, geologic maps, and microscopic and x-ray methods. Three full days of field work. *Wones*

12.232T *Geology II*
Prereq.: 12.231
Year: U (2) 3–4–5
Further survey of the elements of geology: marine topography and sediments; development of landforms by moving water, wind, and ice; production, transportation, and deposition of sedimentary materials; sedimentary rocks; evolution of the earth and its atmosphere and ocean; geological development of the continents; isotopic and biologic methods of dating rocks. Laboratory work on fossils, sedimentary processes, and sedimentary rocks; laboratory case study of the development of the northern Appalachian mountain system. Three or four weekend days of field work. *Naylor*

12.241T *Petrology I*
Prereq.: 12.231
Year: U (1) 3–6–3
Principles and practice of optical crystallography by means of the immersion method of mineral identification. Application of X-ray powder diffraction to the rock-forming minerals. Introduction to the phase equilibria of silicate melts. Heinrich, *Microscopic Identification of Minerals;* Bloss, *Introduction to Optical Crystallography;* Turner and Verhoogen, *Igneous and Metamorphic Petrology.* *Fairbairn, Wones*

12.242 *Petrology II*
Prereq.: 12.241T
Year: U (2) 2–6–4
Distribution, association, and origin of igneous and metamorphic rocks. Laboratory study of igneous and metamorphic rock-forming minerals with petrographic microscope. Turner and Verhoogen, *Igneous and Metamorphic Petrology;* Kerr, *Optical Mineralogy;* Williams, Turner and Gilbert, *Petrography.* *Fairbairn*

12.261 *Paleontology*
Prereq.: 12.232T
Year: U (2) 3–6–3
Study of the plant and animal life of the earth through comparison of fossils and living organisms. Emphasis on use of the fossil record as a basis for paleogeographic and paleoecological reconstructions and stratigraphic interpretations. Lectures, laboratory work, and seashore field trips. Shrock and Twenhofel, *Principles of Invertebrate Paleontology.* (*Alternate years. Not offered 1968–69*). *Shrock*

12.271T *Geology IV*
Prereq.: 12.231
Year: U (1) 3–4–5
Survey of rock structures and mechanics of rock deformation. Elementary concepts of plastic flow and fracture of materials with discussion of observed strains in all types of rocks in relation to mineral deposits, intrusion and metamorphism. Introduction to the geology of North America and survey of the important tectonic elements in other continental and oceanic areas. Laboratory work in map interpretation; five Saturdays of field work on mapping local structures. *Brace*

12.30 *Stratigraphic Research* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a stratigraphic problem. *Shrock*

12.31 *Research in Meteoritics and Geochemistry* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research, especially of an analytical nature. *Pinson*

12.311 *Meteoritics Seminar* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Discussion of current research and advanced topics in meteoritics, including tektite study, with special emphasis on problems of genesis. (*Alternate years.*) *Pinson*

12.34 *Special Topics in Petrology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised studies in the field of petrology. *Fairbairn*

12.35 *Research in Isotope Geology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in isotope geology. *Hurley*

12.352 *Chemistry of the Earth* (A)
Prereq.: 5.60, 18.034
Year: G (2) 3–0–6
Principles of physical geochemistry. Planetary origin and differentiation. Solid and melt phase equilibria, trace element partitioning and generation of magma types. Development of the crust, atmosphere and oceans. Major chemical and geological distributions. Denbigh, *Chemical Equilibrium.* *Hurley*

12.354 *Isotope Geology* (A)
Prereq.: 8.04, 12.231
Year: G (1) 3–0–6
Applications of the variations in the relative abundance of radiogenic and stable isotopes to geologic problems. Topics including geochronology, studies of petrogenesis and the source of ore mineralizations, geologic processes that can be traced by stable isotope fractionations, techniques, and instrument design. *Hurley*

12.36 *Research in Sedimentology or Sedimentary Petrology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in sedimentology or sedimentary petrology. *Staff*

12.361T *Sedimentology and Sediment Movement* (A)
Prereq.: 12.03, 18.02
Year: G (1) 3–0–9
Aspects of turbulent flow mechanics relevant to sediment movement. Modes and mechanics of sediment erosion, transportation, and deposition. Nature and origin of terrigenous sedimentary material. Survey of modern depositional environments. Primary structures and textures in recent and ancient sediments. *Southard*

12.364 *Sedimentology Seminar* (A)
Prereq.: 12.361T
Year: G (1 or 2) 2–0–4
Discussion of current research and problems in sedimentology, sedimentary petrology, and sediment transport mechanics. Content varying from term to term. *Southard*

12.37 *Structural Research* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a structural problem. *Brace*

12.372 *Mechanical Behavior of Crystalline Material* (A)
Prereq.: 8.03T, 18.034
Year: G (2) 3–0–9
Review of symmetry and bonding in crystals. Introduction to cartesian tensors. Review of certain tensor and non-tensor properties of perfect crystals, including elastic, thermal and optical properties, cleavage and fracture, twin and translation gliding and surface properties. Introduction to dislocations and other defects, particularly in rock-forming minerals. Derivation of behavior of aggregates from single crystal behavior with application to rocks under geologic conditions. Nye, *Physical Properties of Crystals.* (*Alternate years. Not offered 1968–69.*) *Brace*

12.373 *Seminar in Structural Geology* (A)
Prereq.: 12.372
Year: G (1 or 2) 2–0–4
Discussion of current research or advanced topics in tectonics, rock mechanics or experimental structural geology. *Brace*

12.38 *Special Topics in Experimental Petrology* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised studies in experimental petrology or geochemistry. *Wones*

12.381T *Experimental Petrology* (A)
Prereq.: 5.60, 12.242
Year: G (1) 3–0–9
Thermostatics and thermodynamics as related to homogeneous and heterogeneous equilibria in mineral systems. Application to the genesis and development of the granitic and basaltic rocks, metasomatism, and metamorphic differentiation. Three Saturdays of field work. *Wones*

12.383 *Rock Forming Minerals* (A)
Prereq.: 5.60, 12.242
Year: G (2) 4–4–4
Application of mineralogy to petrology. Review of the mineralogy of the rock-forming oxides and silicates. Use of mineral equilibria in placing constraints on petrological processes. Laboratory work in determinative mineralogy using X-ray and optical techniques. Emphasis on igneous and metamorphic rocks. Three Saturdays of field work required. *Wones*

12.51 *Geochemical Research* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in geochemistry. *Staff*

12.511 *Geochemistry* (A)
Prereq.: 5.60
Year: G (1) 3–0–6
Study of the distribution of the elements. Application of modern chemical theory to the location of elements in geologic systems, thorough discussion of the existing data of geochemistry, and application of geochemical data to general geologic problems. *F. A. Frey*

(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.

12.52 ***The Chemistries of Natural Aquatic Systems*** **(A)**
Prereq.: 5.60, 18.034
Year: G (2) 3–0–6
Study of marine and fresh waters from three points of view: the theoretical basis for assigning chemical species in solution or suspension and for predicting the chemical reactions which occur; the analytical methods used to measure chemical properties with the objective of assessing what information various analytical schemes provide concerning the chemical species present; our present understanding of the geochemistries and biochemistries of the oceans and fresh waters with the purpose of isolating areas which require further study. (*Not offered 1968–69.*)

12.521 ***Marine Geochemistry*** **(A)**
Prereq.: ——
Year: G (1) 3–0–6
Study of the biological, chemical, and geological parameters in marine sediments in the ocean. Emphasis on the interactions of the aforementioned forces in the sea and sediments and the individual geochemical end products they yield. (*Restricted to students with undergraduate major in chemistry, biology or geology.*) *Degens (Woods Hole Staff)*

12.612 ***Earth and Solar System***
Prereq.: 5.01, 8.03T, *18.034*
Year: U (2) 3–0–9
Selected topics in the physics and chemistry of the earth and solar system. Dynamics of orbits, general properties of the planets; age, evolution, internal structure, and composition of the earth. Interplanetary medium, planetary magnetic fields, solar wind, ionosphere and interactions. *Staff*

12.625J ***Planetary Physics***
(Same subject as 8.281J)
Prereq.: 8.03T
Year: U (1) 3–0–9
Dynamical evolution of the solar system; perturbation theory; tidal forces; resonance interactions. Deduction of gravitational, surface, and atmospheric properties of planets and satellites from ground-based optical, radio, and radar observations and from space-probe experiments. *I. I. Shapiro, McCord*

12.701 ***Physics of the Earth*** **(A)**
Prereq.: 8.03T, 18.034
Year: G (1) 3–0–6
Survey of the earth's interior, thermal regime, composition, structure, elastic and inelastic properties, equation of state as revealed by physical measurements on the surface and on laboratory samples. Reviews results of heat flow, seismology, earth gravity and magnetism, high-pressure geophysics and regional geophysics.
Simmons, Press

12.702 ***Interpretation Methods in Regional Geophysics*** **(A)**
Prereq.: ——
Year: G (2) 3–0–6
Review of methods of data acquisition and analysis in applied and regional geophysics. Appropriate for geologists and geophysicists interested in the solution of geological problems by geophysical field methods. Grant and West, *Interpretation Theory in Applied Geophysics.*
Biehler

12.711 ***Analytic Methods in Applied Geophysics I*** **(A)**
Prereq.: 18.15
Year: G (1) 3–0–6

12.712 ***Analytic Methods in Applied Geophysics II*** **(A)**
Prereq.: 18.15
Year: G (2) 3–0–6
Advanced topics in the analysis and interpretation of geophysical phenomena, including such problems as multilayered media, two-dimensional inhomogeneities, inverse-boundary-value problems, and use of time series analysis in the treatment of current geophysical problems. (*Alternate years.*) *Madden*

12.723 ***Elements of Seismology*** **(A)**
Prereq.: 18.05
Year: G (1) 3–0–9
A basic subject in seismology and the utilization of seismic waves for the study of the earth's interior. Introduction of techniques necessary for understanding of elastic wave propagation in layered media, and dispersion. Seismic ray theory and the interpretation of travel times. Surface wave dispersion and free oscillations of the earth. Seismicity, magnitude, energy. Structure of the earth's interior. *Toksöz*

12.724 ***Advanced Seismology*** **(A)**
Prereq.: 12.723, 18.27
Year: G (2) 3–0–9
Theory of wave propagation in the earth and utilization of seismic data for determining the internal structure of the earth and the physical processes at earthquake foci. Generation of elastic waves from various localized sources; measurement of earth movements; processing of seismic data; seismicity and physics of earthquakes. Some changes from year to year. *Aki*

12.732 ***Geoelectricity and Geomagnetism*** **(A)**
Prereq.: 8.03T, 18.06
Year: G (2) 3–0–9
Survey of the electric, magnetic and electromagnetic properties and processes in the earth's environment. The plasma environment of the earth's magnetosphere and ionosphere and electromagnetic wave and particle phenomena occurring therein. Electric properties of the earth's interior. Magnetohydrodynamic origin of the magnetic fields of the earth and other astronomical bodies. *Madden*

12.742 ***Special Topics on the Electromagnetic Environment of the Earth*** **(A)**
Prereq.: ——
Year: G (2) 3–0–9
Contents varying from year to year, and relating mainly to current research involving the generation, propagation and scattering of electromagnetic waves in the earth's ionosphere and magnetosphere and in interplanetary space. Possible topics: Alfvén wave and whistler phenomena, radio wave propagation and scattering, atmospherics, wave-particle interactions, meteoric phenomena, atmospheric optics, zodiacal light. (*Admission only by permission of instructor. Alternate years.*) *Madden*

12.753J ***Radar Astronomy*** **(A)**
(Same subject as 8.952J)
Prereq.: 8.07T, 18.08
Year: G (2) 3–0–9
Techniques of radar applied to solar-system observations. Theory of scattering of radar waves by planetary surfaces and solar corona. Delay-Doppler mapping. Atomic-clock interferometry. Sun, moon and planet observations; inferences of coronal atmospheric, and surface properties; determination of planetary orbits, spins, sizes, and shapes. Tests of gravitational theories.
I. I. Shapiro

12.762 *Marine Acoustics* (A)
Prereq.: 18.06
Year: G (2) 3–0–6
Marine propagation media, boundary conditions, modern measurement techniques, ray and mode analysis, normal mode theory, stochastic models. Tolstoy and Clay, *Ocean Acoustics*; Prokosky, *Waves in Layered Media;* Albers, *Underwater Acoustics, I and II.*
Hays (Woods Hole Staff)

12.772 *Advanced Marine Geophysics* (A)
Prereq.: 12.702
Year: G (2) 3–0–6
Application of techniques in seismology, earth gravity, geomagnetism, heat flow to outstanding marine problems. Selected subjects from current research and literature. *Von Herzen (Woods Hole Staff)*

12.781-12.788 *Seminar in Geophysics or Planetary Physics* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Problems of current interest in geophysics or in planetary physics; subject matter varying from term to term. *Staff* (12.781, 12.782); *Aki, Toksöz* (12.783); *Madden* (12.784); *Press, Simmons* (12.785); *Biehler* (12.786); —— (12.787); *I. I. Shapiro* (12.788)

12.791-12.798 *Special Problems in Geophysics or Planetary Physics* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
For graduate students desiring to perform special investigations, special laboratory work, or special field work in geophysics or planetary physics.
Staff (12.791, 12.792); *Aki, Toksöz* (12.793); *Madden* (12.794); *Press, Simmons* (12.795); *Biehler* (12.796); *Fiocco* (12.797); *I. I. Shapiro* (12.798)

12.811 *Physical Oceanography*
Prereq.: 8.02, *18.034*
Year: U (1) 3–0–9
Introduction to the physical processes and properties of the oceans; their structure, circulations, and relationships to the atmosphere and solid earth. *(Similar to 19.83.* *Wunsch*

12.901-12.909 *Special Problems in Oceanography* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
For graduate students desiring to perform special investigations, special laboratory work or special field work in oceanography.
Von Arx (12.901); —— (12.902); *Wunsch* (12.903); *Biehler, Press, Simmons* (12.904); *Staff* (12.905–12.907); *Woods Hole Oceanographic Institute Staff* (12.908, 12.909)

12.91 *Research in Physical Oceanography* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
For graduate students pursuing a special investigation of some physical aspect of the oceans. *von Arx*

12.912 *Seminar in Physical Oceanography* (A)
Prereq.: 12.811 or 19.83
Year: G (1, 2) 2–0–7
Reading and discussion of classical and contemporary books and papers having relevance to the marine aspects of earth science. Varying scope and content to meet the special needs and interests of the participants. *von Arx*

12.913 *Marine Geodesy* (A)
Prereq.: 12.811 or 19.83; 19.86
Year: G (1 or 2) 2–0–7
Concepts of classical and modern geodesy considered in relation to physical oceanographic problems; the definition of the geoid at sea by astro-geodetic, gravimetric and satellite techniques; the relief of the physical sea surface with reference to the geoid. *(Admission by permission of instructor only.)* *von Arx*

12.92 *Research in Chemical Oceanography* (A)
Prereq.: ——
Year: G (1 or 2) *Arr.*
Supervised research on a problem in chemical oceanography. *(Not offered 1968–69.)* ——

12.921 *Chemical Oceanography I* (A)
Prereq.: ——
Year: G (1) 3–0–9
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. *(Not offered 1968–69.)* ——

12.922 *Chemical Oceanography II* (A)
Prereq.: 12.921
Year: G (2) 3–0–9
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. *(Restricted to graduate students in geology and geophysics; others admitted only by permission of instructor. Not offered 1968–69.)* ——

12.93 *Waves and Tides* (A)
Prereq.: 18.60
Year: G (1) 3–0–9
Aspects of tide and wave motion in the sea and atmosphere. Derivation of the tide producing forces. Hydrostatic and non-hydrostatic approximations. Oceanic wave motions as examples of geophysical time series; stochastic surfaces, prediction, spectra and bi-spectra, filtering, etc. Content varying from year to year.
Wunsch

12.94 *Biological Oceanography* (A)
Prereq.: ——
Year: G (S) 3–0–6
Principally for non-biologists. Current views of the functioning and effects of organisms in the sea. Emphasis on material pertinent to geochemistry, and physical and chemical oceanography. Initial treatment of basic microbiology and photosynthesis, description of composition of the atmosphere. Short and long time-scale carbon cycles. Other topics such as corals, birds, and high pressure biology solely for their intellectual content. No previous biology necessary. Possible requirement for non-biologists: considerable outside reading in order to become acquainted with the complexity of living systems. *(Given at Woods Hole Oceanographic Institution.)*
Kanwisher (Woods Hole 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.

12.952 ***Physical Properties of Sea Water*** **(A)**
Prereq.: 18.60
Year: G (2) 3–0–6
Equation of state. Thermodynamic potentials. Colligative properties. Equilibria. Diffusion potentials. Energy transformations of a sea water system. (*Given at Woods Hole Oceanographic Institution.*)
Fofonoff (Woods Hole Staff)

12.991-12.999 ***Seminar in Oceanography*** **(A)**
Prereq.: ——
Year: G (1 or 2) *Arr.*
Topics in marine geophysics, physical, dynamical and chemical oceanography. Content varying from term to term. *Staff*

13.

Naval Architecture and Marine Engineering

13.00T ***Principles of Naval Architecture***
Prereq.: 1.05 or 1.612 or 2.201
Year: U (1, 2) 3–1–8
Dynamics and hydrodynamics applied to resistance and propulsion of ships; wave hydrodynamics; propellers and interaction effects between propeller and ship; equations of motion and stability indices for maneuvering of ships and submarines; definitive maneuvers; hydrodynamics of control surfaces; ship motions in regular and irregular seas. Laboratory exercises in ship model towing tank and propeller tunnel. *Kerwin, J. N. Newman*

13.01 ***Applied Hydrostatics***
Prereq.: ——
Year: G (S) 1–7–2
Indoctrination lectures on elementary principles of naval ship design and statics of naval architecture. Work in the project 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. (*Primarily for students in Course* XIII-A; *others admitted with permission of Instructor.*) *Stark*

13.02 ***Propulsion Hydrodynamics*** **(A)**
Prereq.: 1.05 or 2.201; *13.00T*
Year: G (1) 2–0–4
Propulsion devices, particularly marine propellers, similitude and related selection parameters, interaction between propulsion and vehicle, momentum and energy considerations, extremals and optimization, cavitation effects, and special aspects of marine propulsion devices, including unsteady and vibratory considerations. (*Not for students taking 13.22.*) *Powell*

13.03 ***Advanced Hydromechanics of Ship Design*** **(A)**
Prereq.: 13.00T
Year: G (2) 3–0–6
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*

13.04 ***Hydrofoil and Propeller Theory*** **(A)**
Prereq.: *18.06*
Year: G (2) 2–0–4
Development of the theory of hydrofoils in two- and three-dimensional non-cavitating flow following classical aerodynamic theory for incompressible flow, including applications of conformal mapping and thin airfoil, lifting-line, and lifting-surface theory. Topics in propeller theory, including propeller lifting-line and lifting-surface theory and applications to the design of homogeneous flow and wake-adapted propellers. Introduction to unsteady and super-cavitating hydrofoil theory.
Kerwin

13.05 ***Cavity Flows*** **(A)**
Prereq.: 1.631 or 2.25 or 13.04 or 16.02 or 18.60
Year: G (1) 2–0–4
Linear and non-linear cavity flow models at zero and at finite cavitation numbers. Two-dimensional steady and unsteady linearized cavity flows about wedges and hydrofoils. Three-dimensional steady cavity flows. Effects of gravity and boundary surfaces. Compressibility considerations. Theories of planing and water entry. Comparisons of theory with experimental results. Identification of current research problems. Several mathematical approaches introduced to emphasize the method of Muskhelishvili for two-dimensional problems.
Leehey

13.06 ***Unsteady Hydrodynamics*** **(A)**
Prereq.: 2.03 or 13.19; 13.00T or 16.02; *18.06*
Year: G (1) 2–0–4
Topics pertinent to current problems in naval architecture. Added mass and damping of submerged vibrating bodies; reduced frequency. Unsteady hydrofoil theory; lift response to foil oscillation; gust loading; hydroelasticity; flutter. Hydrodynamic excitation of ship vibration. Rotating propeller pressure field; periodic propeller forces in non-uniform flow; wave harmonic analysis. Instrumentation for dynamic measurements. Emphasis on forming computational models. Lectures augmented by water tunnel and towing tank demonstrations. (*Not offered 1968–69.*) *Staff*

13.07 ***Free Surface Hydrodynamics*** **(A)**
Prereq.: 18.06
Year: G (1) 2–0–4
Water wave phenomena pertinent to problems in naval architecture and ocean engineering. Generation, propagation, and diffraction of plane progressive waves. Exciting and restoring forces on floating and submerged bodies. Wave resistance of ships. Wave effects in shallow water and in stratified fluids. *J. N. Newman*

13.10 ***Ship Structural Analysis and Design***
Prereq.: 2.01
Year: U (1) 4–0–8
Hydrostatics; buoyancy and stability of waterborne vehicles in intact, damaged and partially waterborne conditions. 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*

13.11 ***Acoustics and Structural Vibrations***
Prereq.: 2.01, 18.034
Year: G (1) 3–0–6
Elementary solutions of the wave equation. Basic concepts of acoustics: sound intensity and power; radiation impedance; near- and far-field; differences between airborne and waterborne sound. Elementary source configurations. Pressure fields in rigid cavities and pipes. Acoustic transients. Basic concepts of structural vibrations: normal modes; mechanical impedance. Basic

concepts of structureborne noise propagation: phase and group velocity; characteristic impedance. Vibrations of shafts and thin plates. Mathematical models of real structures. Normal-mode analysis of shock response. Effect of damping treatment and resilient mounts on structural vibrations. *Junger*

13.12 *Ship Structural Theory* (A)
Prereq.: 2.01, 2.02
Year: G (1) 3–0–6
Discussion of structural loadings and reactions in naval vessels and the design integration of primary longitudinal hull structure. (*Not recommended for students who have taken 13.10.*) *J. H. Evans*

13.13 *Advanced Structural Theory* (A)
Prereq.: 13.10 or 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 loads, stiffened cylindrical shells, and ship oscillation loadings. *J. H. Evans*

13.14 *Ship Structural Design I* (A)
Prereq.: 13.10 or 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. *J. H. Evans*

13.15 *Ship Structural Design II* (A)
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. *J. H. Evans*

13.16 *Naval Structural Design* (RA)
Prereq.: 13.13
Year: G (1) 0–5–0
Development of primary transverse structures such as bulkheads and ring frames for surface ships and submarines. Pressure vessel analysis and design. Discussion of structures under dynamic loading due to air blast, underwater explosion and pounding. (*Restricted to selected officers of U.S. Navy and Coast Guard.*) *J. H. Evans*

13.17 *Ocean Engineering Structures* (A)
Prereq.: 2.01
Year: G (1) 3–0–6
Seminar on the structural design of semi-submerged mobile drilling platforms, bottom supported towers, submarine vehicles, bottom habitations and stayed structures. Brief treatment of the evaluation of towing, mooring, wave, jacking and bottom suction loads needed for the structural design of these vehicles and platforms. Configuration optimization of pressure chamber structures, moorings, buoy systems and anchoring devices. Emphasis on selection of materials. *J. H. Evans*

13.18 *Ship Structural Dynamics* (A)
Prereq.: 2.03 or 13.11 or 13.19
Year: G (2) 3–0–6
Dynamic response of ship structural configurations in the elastic and plastic range. Elastic response of ship structures to wave generated loads, slamming pressures and propeller or machinery generated forces; extension to plastic deformation and ultimate failure. Derivation of loads associated with explosive effects both under water and in air and the elastic and plastic response of ship structures and shipboard installations to these explosive loads. *N. Jones*

13.19 *Mechanical Vibration* (A)
Prereq.: 2.01, 2.02
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*

13.20 *Energy Conversion Systems and Components*
Prereq.: 2.01, *2.201*, 2.403
Year: U (2) 4–0–8
Energy conversion devices and systems of types applicable to ships and ocean engineering vehicles, involving thermal, mechanical, hydraulic, and electrical machinery; interaction of coupled devices under steady-state and transient conditions; optimization principles. *Powell*

13.21 *Ship Propulsion* (A)
Prereq.: 2.403, 2.54
Year: G (1) 2–0–4
Critical examination of ship propulsion requirements and the machinery systems and components used to satisfy them. Design and analysis projects on a professional level. This subject together with 13.02 represents substantially the material covered in 13.22. *Powell, Reed*

13.22 *Naval Ship Propulsion* (A)
Prereq.: 2.402, 2.54
Year: G (1) 4–2–6
Critical examination of naval ship propulsion requirements for the design of systems and components. Selection of propulsion devices and system parameters to satisfy ship performance requirements or demonstrate feasibility. Optimization of propulsion system parameters on the basis of minimum weight or other constraints. Design and analysis projects and calculation specially selected to stimulate professional application of engineering fundamentals. (*Primarily for students in Course* XIII-A*; others admitted with permission of Instructor.*) *Reed, Powell*

13.23 *Propulsion System Reliability and Control* (A)
Prereq.: 6.28 or 13.60 or 18.10 or 18.18
Year: G (2) 3–0–6
Application of statistical and operations research methods to complex system reliability. Classical constant component failure rate models, systems with component interaction, wear, environmental effects, resulting in time- and wear-dependent failure rates. Markov models, systems availability, preventative and corrective maintenance scheduling. Dynamics and control of marine power plants. *Frankel*

13.25 *Advanced Naval Electrical Engineering* (RA)
Prereq.: 6.03
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. Not offered 1968–69.*) *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.

Descriptions

13.40 ***Introductory Ship Design***
Prereq.: 13.00T, 13.10
Year: U (2) 1–6–5
Engineering and economic principles involved in the selection of dimensions and coefficients of commercial ships; design of hull form, internal arrangements, midship section, and estimation of performance criteria in a comprehensive design exercise. *Mandel*

13.41 ***Principles of Ship Design*** **(A)**
Prereq.: 13.00T; 13.10 or 13.12
Year: G (1) 2–4–5
Fundamental distinction among waterborne 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. (*Not recommended for students who have taken 13.40.*) *Mandel*

13.42 ***Design of a Waterborne Vehicle*** **(A)**
Prereq.: 13.41
Year: G (1, 2) *Arr.*
Determination of performance criteria for a waterborne vehicle or platform based on an arbitrary set of system mission requirements established by the student in consultation with instructor. Preparation of the preliminary design of the vehicle or the floating platform fulfilling the selected performance criteria. Participation by several students in a single project encouraged. *Mandel*

13.43 ***Naval Ship-System Design I*** **(A)**
Prereq.: 13.00T
Year: G (S) 3–0–6
Principles involved in the design of selected hull, electrical, machinery and weapon systems for naval ships and their influence on the configuration and arrangement of ships. (*Primarily for students in Course* XIII-A*; others admitted with permission of Instructor.*) *Stark*

13.44 ***Naval Ship-System Design II*** **(RA)**
Prereq.: 13.43
Year: G (1) 0–5–0
Analyses of problems involved in the design of naval ship systems and their incorporation in a ship. Preparation of drawings to reflect the results of these studies. (*Restricted to selected officers of the U.S. Navy and Coast Guard.*) *Stark*

13.45 ***Principles of Naval Ship Design*** **(RA)**
Prereq.: 13.43
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.*) *Stark*

13.46 ***Conceptual Design of Naval Ships*** **(RA)**
Prereq.: 13.41, 13.43, 13.45
Year: G (2) 0–9–3
Project-type studies, including preparation of necessary drawings and calculations to support formulation and preliminary design of naval ships. (*Restricted to selected officers of the U.S. Navy and Coast Guard*). *Stark*

13.47J ***Special Studies in Systems Engineering*** **(A)**
(Same subject as 1.16J, 2.191J, 6.604J)
Prereq.: 13.20, 13.41, 13.60
Year: G (2) 2–4–6
Introduction to basic techniques employed in planning and design of complex systems. Detailed design of subsystems by individual student groups with emphasis upon use of parametric design principles in arriving at suitable tradeoffs between subsystems. Supplementing lectures covering general principles of the operational complex and subsystems by guest lecturers. The particular operational complex chosen for each term to be announced before start of the term. Students encouraged to discuss subject with staff prior to registration. (Previous projects: Group 1 — integrated urban transportation system. Group 2 — manned satellite inspection and retrieval system.) *Frankel, de Neufville, Baumann, Seifert*

13.50 ***Computer Approaches to Problems in Naval Architecture and Marine Engineering***
Prereq.: 18.05
Year: G (2) 2–2–4
Steps required in the development of useable computer programs for the solution of engineering problems including problem definition, numerical analysis, program organization, FORTRAN IV programming, M.I.T. Information Processing Services Center operating procedures, development of program tests, debugging and program documentation. Assigned projects and lectures based on realistic problems in naval architecture and marine engineering selected to illustrate many of the advantages and difficulties encountered in computer applications. (*Primarily for seniors and graduate students in naval architecture and marine engineering; others admitted by permission of the instructor.*) *Kerwin*

13.51 ***Computer Systems for Naval Architecture and Marine Engineering*** **(A)**
Prereq.: 1.151 or 2.101 or 3.73 or 6.47 or 13.50
Year: G (2) 2–0–4
Principles of computer systems and their application to ship design and construction. Role played by various types of equipment in a system; program definition and organization; principles of compilers, interpreters, monitor systems, and problem oriented languages. Translation of functional requirements, file design, data control and supporting systems in the context of naval architecture, considering broadly based applications in preliminary design, machinery, structures and fabrication, and construction management. Review of systems currently under development. *Romberg*

13.60 ***Application of Operational Methods***
Prereq.: 18.034
Year: U (1) 4–0–8
Elementary probability theory and statistics. Linear, non-linear, and dynamic programming. Inventory control, game theory, and queuing. Flow graphs and elementary control theory. Methods of applications to transportation, distribution, and marine design problems. Shipping system analysis, including scheduling and flow procedures, decision strategies, and information search. *Frankel*

13.61 ***Decision Processes in Ship Operation and Construction*** **(A)**
Prereq.: 6.28 or 13.60 or 18.10; 13.00T, 13.10; 13.20; 14.01
Year: G (2) 3–0–6
Development of techniques which optimize decisions in the face of uncertainty on a long-term basis. Analysis of legal, financial, assurance, political, trade, labor, and administrative factors influencing the shipping venture. Routing and scheduling. Bayesian statistics and decision theory. Information flow and system response prediction. Critical path and networks. PERT II. Integration of transportation systems. *Frankel*

13.62 ***Shipping Economics*** **(A)**
Prereq.: 13.00T, 13.20, *13.40*
Year: G (2) 3–0–6
Economic aspects of ship operation and design, including application of engineering economic principles to the

evaluation of shipping enterprises as systems and their components. Principles of optimization and semi-analytical techniques applicable thereto. Students with a background in transportation engineering who lack prerequisites may apply to the instructor for admission. *Powell*

13.63 *Hydrospace Vehicles and Their Use*
Prereq.: ——
Year: U (1) 3–0–9
Development of performance criteria common to all vehicle types. Physical principles governing the performance of submarines, surface ships, hydrofoils, planing craft and surface effect ships. Comparison to aircraft. Impact of technological advances in power plants, structural materials and thrusters on the performance of hydrospace vehicles. Economic criteria governing the role of these vehicles in peaceful pursuits. Performance of these vehicles in a wartime environment. (*Credit will not be given for both 13.63 and 13.64. Not offered 1968–69.*) *Mandel*

13.64 *Hydrospace Vehicles*
Prereq.: ——
Year: U (2) 2–0–4
Abridgement of 13.63. (*Credit will not be given for both 13.63 and 13.64.*) *Mandel*

13.65 *Ship Production Analysis* (A)
Prereq.: 13.40 or 13.41; 13.60
Year: G (1) 2–0–4
Operations research; mathematical and econometric models of ship production. Production process design and control. Modern production techniques. Network and flow analysis. *Frankel*

13.70 *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. *Powell*

13.71 *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. *Powell*

13.72 *Fundamentals of Signal Measurement and Handling* (A)
Prereq.: 6.01, 18.06
Year: G (2) 3–0–9
Intended for students in ocean engineering, oceanography and other non-electrically oriented science and engineering disciplines as a subject in instrumentation fundamentals. Introduction to the mathematical basis and applications, including linear systems, lumped parameter electric circuits, active filters, harmonic analysis, random processes, correlation functions, power spectra detection of signals in the presence of noise, and sampling theory; the transmission of signals through linear systems; stability criteria. *Milgram*

13.92J *Public Policy and Use of the Seas*
(Same subject as 17.443J)
Prereq.: ——
Year: G (1) 3–0–6
Policies of the United States and other nations toward possession and use of the seas. Interfaces between technology and public policy. Laws and agreements relating to jurisdiction in the maritime frontier, use of Continental Shelf, navigation, exploitation of ocean resources, deep submergence, and pollution. Role of the U.N. and other agencies. New goals for national policy. *Padelford*

13.95 *Hydroacoustics* (A)
Prereq.: 13.11, 18.06
Year: G (2) 3–0–6
Topics in underwater acoustics important to modern naval architecture and marine engineering. Physics of water; mechanism of cavitation; cavitation 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. *Leehey*

13.97 *Acoustics of Submerged Structures* (A)
Prereq.: 2.03 or 13.11 or 13.19; 18.06
Year: G (2) 3–0–6
Sound radiation by plane circular and rectangular sources. Radiation and scattering by spheres and cylinders. Asymptotic formulations of the far-field and of high-frequency radiation. Vibrations of shells and of thick plates; effect of stiffeners. Vibrations of force-excited submerged shells and plates and associated sound radiation. Sound transmission and scattering by elastic plates and shells. Transient interaction between a pressure step-wave and an elastic shell (linear theory). Velocity source in an elastic baffle. Pressure field in elastic cavities and pipes. Effect of damping and resilient coatings on sound radiation. Theory of scaled model tests. *Junger*

13.98 *Stability and Motion Control of Ocean Vehicles* (A)
Prereq.: 13.00T, 13.10, 18.05; or 13.03
Year: G (1) 3–0–6
Interaction between surface waves and surface and near surface free-floating bodies. Principles of design of control systems to reduce wave excited, six degree of freedom body motions to acceptable specified levels at zero speed and at finite ahead speed. Vehicle and platform design principles leading to motion reduction. Applications to ships, catamarans, oil drilling platforms, mohole type platforms and flipships. Precise motion control of submerged vehicles at very low speeds. Note: 13.03 will be helpful as additional preparation. *Abkowitz*

13.99 *Mooring and Towing Mechanics* (A)
Prereq.: 2.03 or 13.19; 13.00T; 13.10 or 13.12 or 13.17
Year: G (2) 3–0–6
Motion, position and loads in surface and submerged anchored buoy systems; surface vessels restrained by buoyed and other mooring arrangements under influence of currents, waves and applied loads. Stability and control of submerged towed and self propelled tethered devices and associated cable. Cable catenary, loads and drag for both towed and self propelled tethered devices. Mean depth of a towed or tethered device and its motion and cable loads due to motions of towing vehicle. Acoustic interference with towed hydrophones or sonars due to flow noise and radiated noise of towing vehicle. (*Not offered 1968–69.*) ——

(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.
Economics

GENERAL ECONOMICS AND THEORY

14.01 *Economic Principles I*
Prereq.: ——
Year: U (1, 2) 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. *Eckaus*

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, partial and general, of the firm, household, production and markets, treated at the intermediate level. Emphasis on applications, such as cost-benefit analyses, price regulation, technical change, and income distribution. *Rothenberg*

14.04T *Intermediate Microeconomic Theory*
Prereq.: 14.02
Year: U (1) 4–0–8
Basic theory of consumer behavior, production, pricing, market structures in a partial equilibrium framework, general equilibrium, welfare, and capital. (*Credit given only for either 14.03 or 14.04T.*) *Foley*

14.05 *Economic Fluctuations and Growth*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
Theory of income determination, static and dynamic. Emphasis on applications to fiscal and monetary policy. *J. R. Harris*

14.06T *Intermediate Macroeconomic Theory*
Prereq.: 14.02
Year: U (1) 4–0–8
Theory of national income determination, static and dynamic; components of aggregate demand; national accounts. Theory of growth and inflation. (*Credit given only for either 14.05 or 14.06T.*) *Sidrauski*

14.09 *Economic Problems Seminar*
Prereq.: 14.02
Year: U (1, 2) 3–0–5
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. (*Not offered 1968–69.*) ——

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, maxima and minima, definite integral, Taylor's series, partial derivatives, homogeneous functions, implicit function theorem, and constrained maxima and minima. *Rees*

14.102 *Mathematics for Economists*
Prereq.: 14.101
Year: G (2) 3–0–6
Continuation of 14.101. Single equation linear difference and differential equations; vector spaces and matrices; system of linear difference and differential equations and latent roots; properties of non-negative square matrices. *Fisher*

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.*) ——

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.*) *Millikan, 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*

14.121 *Economic Analysis I* (A)
Prereq.: 14.04T
Year: G (1) 4–0–8

14.122 *Economic Analysis II* (A)
Prereq.: 14.121
Year: G (2) 4–0–8
General theory of equilibrium under competition and monopoly. Theory of consumer choice, of demand, of the firm, of production and distribution, of welfare economics. *Bishop (14.121), Samuelson (14.122)*

14.123 *Advanced Economic Theory I* (A)
Prereq.: 14.102, 14.122
Year: G (1) 3–0–6
Topics centered around modern general equilibrium theory and its extensions. Linear programming, the simplex and duality theorems, and relation to economic analysis. Leontief systems, non-negative square matrices, the Hawkins-Simon and other conditions. Existence, optimality, and stability of competitive equilibrium. The von Neumann model of production as extended; prices and outputs. The turnpike theorem and related topics. *Liviatan*

14.124 *Advanced Economic Theory II* (A)
Prereq.: 14.122
Year: G (2) 3–0–6
Special topics in economic theory, drawn from microeconomics and macroeconomics. Content varying from year to year; current emphasis on theory of capital and behavior under uncertainty. *von Weizsäcker*

14.132 *Schools of Economic Thought* (A)
Prereq.: 14.121
Year: G (1) 3–0–6
Economic ideas developed by different groups of economists in recent times. *Samuelson*

14.151 *Mathematical Approach to Economics* (A)
Prereq.: 14.122
Year: G (2) 3–0–6
The use of mathematical methods in all the fields of economics. *Samuelson*

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.

14.193 ***Seminar: Topics in Economics*** **(A)**
Prereq.: 14.121, 14.451
Year: G (1) 3–0–6

14.194 ***Seminar: Topics in Economics*** **(A)**
Prereq.: 14.122, 14.452
Year: G (2) 3–0–6
Topics in economics of current interest.

14.195 ***Reading Seminar in Economics*** **(A)**
Prereq.: 14.121
Year: G (1) *Arr.*

14.196 ***Reading Seminar in Economics*** **(A)**
Prereq.: 14.121
Year: G (2) *Arr.*
Reading and discussion of special topics in economics. Open to advanced graduate students by arrangement with individual members of the staff. *Staff*

INDUSTRIAL ECONOMICS

14.20 ***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. *R. W. Crandall*

14.22 ***Economics of Particular Industries***
Prereq.: 14.03 or 14.04T
Year: U (1) 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 1968–69.*) *R. W. Crandall*

14.23 ***Economics of Fuel and Power***
Prereq.: 14.02
Year: G (2) 2–0–4
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. Intended for students of either economics or engineering. *Adelman*

14.231 ***Seminar in the Economics of Eastern Hemisphere Petroleum*** **(A)**
Prereq.: 14.04T
Year: G (1) 2–0–6
Joint seminar with Harvard, meeting at Center for Middle East Studies weekly. Basic production economics, market structure, price evolution, company-government relations, energy policy in Western Europe. (*Not offered 1968–69.*) *Adelman*

14.271 ***Problems in Industrial Economics*** **(A)**
Prereq.: 14.04T
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*

14.282 ***Economics of Technology and Innovation*** **(A)**
Prereq.: 14.03
Year: G (1) 3–0–6
Comparison of the economic, engineering and business concepts of technology. Economic significance of technological constraints. Review of theories of innovation and its effects both at the level of the individual firm and for the over-all economy, with case studies of innovation process. Analysis of special problems of technological adaptation in less-developed areas. Economics of research and education and training. *Eckaus*

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 ***Econometrics***
Prereq.: 14.381
Year: U (1) 3–0–6
Introduction to basic econometric techniques with strong emphasis on applications. Problems in estimating such economic variables as consumption-income-price relationships, production functions, and in simulating economic models. *Kuh*

14.371 ***Statistical Theory***
Prereq.: 18.02
Year: U (1) 3–0–6
Axiomatic probability, random variables, mathematical expectation, generating functions, probability distributions, convolution, correlation, regression, and elementary stochastic processes. *Rees*

14.372 ***Statistical Theory*** **(A)**
Prereq.: 14.371
Year: G (2) 3–0–6
Sampling theory, statistical estimation, the Gauss-Markov theorem and least squares, testing statistical hypotheses, the general linear hypothesis *Rees*

14.373 ***Time-Dependent Probability*** **(A)**
Prereq.: 14.371 or 18.10
Year: G (1) 3–0–6
Markov chains and Markov processes, the relevant ergodic theorem, Kolmogorov equations, time series theory: spectral density functions, harmonic representation, autoregressive models. *H. A. Freeman*

14.374 ***Design and Analysis of Scientific Experiments*** **(A)**
Prereq.: 14.371 or 18.10
Year: G (1) 3–0–6
Linear hypotheses and the associated analysis of variance. Discussion ranging from simple experimental designs to experimental designs involving many factors and many variables. *H. A. Freeman*

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14.381 ***Statistical Method***
Prereq.: 14.101 or 18.02
Year: U (2) 3–0–6
Self-contained subject in statistics which also serves as a background for advanced study in econometrics. Elements of probability theory, point estimation, interval estimation, hypothesis testing, introduction to regression analysis. *H. A. Freeman*

14.383 ***Econometric Theory*** **(A)**
Prereq.: 14.102; 14.372 or 14.381
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 newer estimation procedures. *Fisher*

14.384T ***Applied Econometrics*** **(A)**
Prereq.: 14.383
Year: G (2) 3–0–6
Econometric applications to supply and demand analysis and macroeconomic models. Emphasis on using structural econometric models for policy and forecasting. An empirically oriented term paper required. *Kuh*

14.386 ***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. (*Not offered 1968–69.*) *Fisher*

14.39 ***Economic Research Seminar***
Prereq.: 14.04T, 14.06T, 14.381
Year: U (1) 2–0–6
Introduction to research procedures in economics in preparation for thesis. Students to prepare reports on research topics. *Foley*

14.393 ***Doctoral Dissertation Seminar*** **(A)**
Prereq.: 14.122, 14.452
Year: G (1) 2–0–7

14.394 ***Doctoral Dissertation Seminar*** **(A)**
Prereq.: 14.122, 14.452
Year: G (2) 2–0–7
Seminar for students writing doctoral dissertation. Presentation by students and discussion of dissertation research in various stages of completion. *Staff*

NATIONAL INCOME AND FINANCE

14.40 ***Monetary and Banking Policy***
Prereq.: 14.06T
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, and international financial relations. *Foley*

14.41 ***Distribution of Income and Employment Opportunity***
Prereq.: 14.02
Year: U (2) 3–0–5
Analysis of public policies deriving from concerns about the equity of the distribution of income and employment opportunities in the United States. Particular attention to social security, medicare, the "war on poverty" and the economic problems of Negro Americans. *Piore*

14.43 ***Public Finance***
Prereq.: 14.03 or 14.04T; 14.05 or 14.06T
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.: 14.06T
Year: G (1) 4–0–8
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) 4–0–8
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. *Sidrauski*

14.462 ***Monetary Economics I*** **(A)**
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6
Examination of sources and determinants of supply of money with special attention to roles of commercial banks, Federal Reserve System, and Treasury. Discussion of nature of demand for money. Role of monetary policy in determination of level of economic activity. *Modigliani*

14.463 ***Monetary Economics II*** **(A)**
Prereq.: 14.122, 14.452
Year: G (1) 3–0–6
General equilibrium theory of money, interest, prices, and output; portfolio problems, cost of capital, and the effects of monetary phenomena on investment and accumulation of wealth with special reference to problems arising from uncertainty. *Sidrauski*

14.471 ***Fiscal Economics I*** **(A)**
Prereq.: 14.121, 14.451
Year: G (1) 3–0–6

14.472 ***Fiscal Economics II*** **(A)**
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6
Examination, both theoretic and quantitative, of governmental fiscal institutions and behavior: the budget process, taxation, expenditure, pricing, and debt activities. *Thurow (14.471); E. C. Brown (14.472)*

14.474 ***Seminar in Fiscal and Monetary Policy*** **(A)**
Prereq.: 14.462 or 14.471; 14.463 or 14.472
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, Thurow*

INTERNATIONAL, INTERREGIONAL AND URBAN ECONOMICS

14.51 ***Urban Economics***
Prereq.: 14.02
Year: U (1) 3–0–5
Analysis of selected economic problems of urban areas in the United States. The housing market: demand and supply, growth, aging and urban renewal. The economics of race in the metropolitan area, the Model Cities Program. The nature and problems of government decision making in metropolitan areas, including urban-suburban relations; market and governmental interactions. Applied normative analysis; criteria for public expenditures; cost-benefit analysis. In each of these topics, emphasis on the resource allocation process, its efficiency, and sources of suboptimality. *Edel*

14.52 ***Economics of the Soviet Union***
Prereq.: 14.02
Year: U (2) 3–0–5
Historical background. Russian agriculture and industry before the Communist revolution. Economic ideology of the Communist regime. General approach to industrialization. Allocation of resources. Agriculture and

industry. Management and labor. Recent changes and discussions. Evaluation of the Soviet experiment. Lessons for underdeveloped countries. (*14.53 is desirable preparation but not a prerequisite.*) *Domar*

14.53 *Comparative Economic Systems*
Prereq.: 14.02
Year: U (1) 3–0–5
Analytical study of economic problems in different economic systems. The economic ideology of capitalism, utopian writings, Marxism and socialism. Comparison of several capitalist and socialist countries, including the United States, West Germany, Sweden and Yugoslavia. Role of the price system, investment decisions, economic growth, etc. *Domar*

14.54 *International Trade*
Prereq.: 14.04T, 14.06T
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. *Bhagwati*

14.572J *Urban Economics: Positive Analysis I* (A)
(Same subject as 11.66J)
Prereq.: 14.03 or 14.04T
Year: G (2) 3–0–6
Economic analysis of urban areas in their regional setting, organized around the sources, characteristics, and implications of spatial concentration of economic activities. Consideration of both market and governmental forces. Location theory; spatial competition; general equilibrium models of interregional economic activity with emphasis on input-output and linear programming models; interregional transmission of economic fluctuations; metropolitan growth and development. Explicit attention to spatial factors affecting the demand for transportation services. *Paelinck*

14.573J *Urban Economics: Positive Analysis II* (A)
(Same subject as 11.67J)
Prereq.: 11.66J or 14.572J
Year: G (1) 3–0–6
Continuation of 14.572J. The land use market and the spatial structure of the metropolitan community. Models of the metropolis. The housing market: demand and supply, growth, aging and urban renewal. The economics of race in the metropolitan area, the Model Cities Program. The urban transportation system and its problems. In each of these topics, emphasis on the resource allocation process, its efficiency, and sources of suboptimality. *Rothenberg*

14.574J *Urban Economics: Positive and Normative Analysis III* (A)
(Same subject as 11.68J)
Prereq.: 11.67J or 14.573J
Year: G (2) 3–0–6
Continuation of 14.573J. The nature and problems of government decision making in metropolitan areas. Urban-suburban relations: market and governmental interactions. Optimal and suboptimal government. Welfare economics and the normative theory of local public policy. Applied normative analysis: criteria for public expenditures; cost-benefit analysis. Examination of public policy issues in current urban problems: poverty, race, the spatial form of the city, optimal land use patterns, growth and renewal. *Rothenberg*

14.581 *International Economics I* (A)
Prereq.: 14.04T, 14.06T
Year: G (1) 4–0–8

14.582 *International Economics II* (A)
Prereq.: 14.581
Year: G (2) 4–0–8
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.
Bhagwati (14.581); Kindleberger (14.582)

14.584 *Seminar in International Economic Theory* (A)
Prereq.: 14.582
Year: G (2) 2–0–7
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. *Bhagwati, Kindleberger*

14.586 *Interregional Economics* (A)
Prereq.: 14.04T
Year: G (2) 3–0–6
Problems of economic analysis as affected by the geographical separation of resources and markets; factors leading to interregional trade; the role of transportation with particular reference to national transportation policy; problems of industrial location and regional competition; interregional adjustment of diverse economic activities; regional economic planning in the context of national economic policy. (*Not offered 1968–69.*)
J. R. Harris

LABOR ECONOMICS AND INDUSTRIAL RELATIONS

14.63 *Labor Relations*
Prereq.: ——
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. *Piore*

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. *Mills*

14.671J *Labor Economics* (A)
(Same subject as 15.671J)
Prereq.: 14.64 or 15.312
Year: G (2) 3–0–6
Primary emphasis on the determination of wage levels and wage differentials through an analysis of labor supply and labor demand, as affected by economic as well as by institutional factors. The impact of unions on both wage and non-wage elements of collective bargaining in the light of the characteristics and objectives of particular unions. Other special topics growing out of recent research in labor economics. (*Not offered 1968–69.*)
C. A. Myers

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14.672J *Public Policy on Labor Relations* (A)
(Same subject as 15.672J)
Prereq.: 14.64 or 15.312
Year: G (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. *Piore, D. V. Brown*

14.674J *Comparative Industrial Relations Systems* (A)
(Same subject as 15.674J)
Prereq.: 14.64 or 15.312
Year: G (1 or 2) 3–0–6
International and comparative analysis of industrial relations problems and experience. (1) A review of traditional theories of the labor movement. (2) A survey of recent theorizing about management and labor problems in economic development. (3) Examination of selected issues involving interest groups and the strategies of economic development, including discussion of the nature and functions of labor and management organization in different contexts; the role of the state in establishing procedures and in shaping the substance of industrial relations; the participation of interest groups in the formulation of economic and social policy; manpower and economic growth; external influences on national industrial relations systems. *Siegel*

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 15 students. Not offered 1968–69.*) ——

14.691J *Research Seminar in Industrial Relations* (A)
(Same subject as 15.691J)
Prereq.: 14.671J or 14.672J
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.
Siegel, Haire

14.692J *Research Seminar in Industrial Relations* (A)
(Same subject as 15.692J)
Prereq.: 14.691J
Year: G (2) 3–0–6
Continuation of 14.691J. *Siegel, Haire*

ECONOMIC HISTORY

14.71 *Economic History*
Prereq.: 14.02
Year: U (1) 3–0–5
Survey of growth in the American and/or European economy in the nineteenth and twentieth centuries. Topics including the economic effects of governmental policies, the causes and effects of technical change, the role of specific institutions, the economic causes of political conflicts. Content varying from year to year, with emphasis usually on the United States. (*Not offered 1968–69.*) *Temin*

14.731 *American Economic History* (A)
Prereq.: 14.121
Year: G (1) 3–0–6
Basic survey of the beginnings of American industrialization, emphasizing a quantitative approach and the period from 1760 to 1860. The nature of the colonial economy, economic problems of political independence, factors inducing the growth of industry (and specific industries), problems of antebellum agriculture and slavery. *Temin*

14.732 *European Economic History* (A)
Prereq.: 14.121
Year: G (2) 3–0–6
Selected topics in recent European economic history with special attention to problems associated with technical progress, productivity, and changes in economic and social structure. ——

14.733 *European Economic History* (A)
Prereq.: 14.731 or 14.732
Year: G (1) 3–0–6
Development of European economy from the fall of the Roman Empire through the Industrial Revolution. Analysis of the settlement of Europe, the manorial system, the appearance of town and national economies, colonialization, and industrialization in terms of economic theory in order to clarify the nature of economic growth. (*Not offered 1968–69.*) ——

14.734 *Problems in Economic History* (A)
Prereq.: 14.731 or 14.732
Year: G (2) 3–0–6
Analysis of problems of industrial society, concentrating on the century after 1860 and on the American experience. Subject matter varying from year to year on topics such as the effects of wars on welfare and growth, the nature of the long deflation of the late nineteenth century, the contrast in international relations before and after 1914, the depression of the 1930's. (*Not offered 1968–69.*) *Temin*

ECONOMIC DEVELOPMENT

14.74 *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. *Edel*

14.771 *Problems of Economic Development* (A)
Prereq.: 14.772
Year: G (1) 3–0–6
Applications of development theory. Studies of structure of less-developed economies, technological constraints, interaction of foreign trade and internal development, international financial problems. *Rosenstein-Rodan*

14.772 *Theory of Economic Development* (A)
Prereq.: 14.121, 14.451
Year: G (2) 3–0–6
Analysis of theories of economic development with attention to alternative patterns of resource scarcity, population growth, and models of growth. Econometric and programming models for planning. Investment criteria in less-developed countries. *Eckaus*

14.773 *Seminar in Economic Development* (A)
Prereq.: 14.772
Year: G (1) 3–0–6
Special problems in economic development such as international trade policy, monetary and fiscal issues, and problems of particular sectors with special attention to agriculture. *Bhagwati*

14.774 ***Seminar in Economic Development*** **(A)**
Prereq.: 14.772
Year: G (2) 3–0–6
Studies of current issues in the economic development of particular countries and regions which will normally include India and some other countries in Southeast Asia, countries in Latin America, Africa and the Middle East. *Millikan*

14.782 ***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*

14.784 ***Elements of Economic Growth***
Prereq.: 17.721
Year: G (1) 3–0–6
Introduction to the economic theory of growth for students without graduate training in economics. Introduction to relevant technical economic concepts in income, employment, and production theory. *Hagen*

15.
Management

15.012 ***Economics for Management I***
Prereq.: ——
Year: G (1) 3–0–6
Microeconomics for students of management. How the price-profit system works through operation of supply and demand. Market structures and market behavior in specific industries. Regulation of competition. *(Restricted to Sloan School of Management graduate students; others admitted only with permission of instructor.)* *MacAvoy*

15.014 ***Economics for Management II***
Prereq.: 15.012
Year: G (2) 3–0–6
Macroeconomics for students of management. Study of the determination of national income and the level of economic activity; monetary economics and growth; prices and business cycles; stabilization policies, monetary and fiscal, and balance of payments problems. *(Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.)* *Thurow*

15.019 ***Seminar in Economics for Management*** **(A)**
Prereq.: 15.014
Year: G (2) 3–0–6
Review of basic economic theories of the firm, the industry and the economy, with emphasis on those aspects useful for analyzing the American experience. Detailed discussion of case studies applying the theories, including industry studies of the pricing effects of market structure, economy-wide forecasts, and studies of the effects of government regulatory, monetary, and fiscal policies. *(Restricted to doctoral candidates in the Sloan School of Management.)* *MacAvoy*

15.02 ***Industrial Statistics***
Prereq.: 18.034
Year: U (1, 2) 4–0–8
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*

15.032 ***Sampling of Finite Populations*** **(A)**
Prereq.: 15.02 or 15.092
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 subsampling; multistage sampling; combinations of cluster sampling and stratified sampling; disproportionate stratified sampling; two-phased and sequential sampling. *Durand*

15.05 ***Introduction to Management***
Prereq.: ——
Year: U (2) 4–0–8
Introduction to what a business is, how it relates to the environment within which it operates, and how it operates; an over-all appreciation of the global problems of planning, making decisions, organizing, directing, operating and controlling a business. *Goetz, Roberts*

15.06 ***Managerial Psychology***
Prereq.: ——
Year: U (1, 2) 3–0–6
Core subject for all students majoring in management. Survey of individual and social psychology and organization theory interpreted in the context of the managerial environment. *Allen*

15.07 ***Managerial Economics***
Prereq.: ——
Year: U (1) 4–0–8
Introduction to fundamental concepts of the economics of the firm and of industry. The mechanisms of supply and demand. Operation of the price-profit system. Market structures and market behavior in specific industries. Analyses of economic problems of relevance to management. *MacAvoy*

15.08 ***Managerial Environment***
Prereq.: 15.05, 15.06, 15.07
Year: U (2) 4–0–8
The nature of the environment affecting the operation and growth of purposeful organizations. Social, political, and technological changes, and their impact on managerial problems and responsibilities. The multidimensional character of issues posed by environmental changes. Interaction of business, government, and nonprofit organizations with technology and society at large. *Staff*

15.091 ***Mathematics for Management***
Prereq.: ——
Year: G (1) 4–0–8
Introduction to probability and statistics emphasizing applications to management problems. Such topics as set theory, basic probability theory, an introduction to decision making under uncertainty, Bernoulli, Poisson, normal, and Markov processes and aspects of statistical inference. *(Restricted to Sloan School of Management graduate students.)* *L. S. White*

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15.092 *Mathematics for Management*
Prereq.: ——
Year: G (2) 4–0–8
Introduction to mathematical programming emphasizing applications to management problems. Such topics as matrix algebra, classical optimization techniques, linear programming, integer and non-linear programming, dynamic programming, and heuristic programming. *L. S. White*

15.094 *Statistical Decision Theory I*
Prereq.: 6.28
Year: U (2) 3–6–0
Decision making under uncertainty. Rationales of decision makers, utility, the concept of the value of perfect information. The Bayesian approach. Preposterior, optimal fixed-size, and other forms of analysis of statistical decision problems. *Kaufman*

15.095 *Statistical Decision Theory* (A)
Prereq.: 6.28
Year: G (2) 3–0–6
Development of a basic theory of decision making under uncertainty. Rationales of decision makers, utility, the concept of the value of perfect information. The Bayesian approach to decision making; its relationship to classical statistics. Pre-posterior analysis and optimal fixed-size analysis for common random processes. Discussion of normal vs. extensive form analysis of statistical decision problems. *Kaufman*

15.099 *Seminar in Applied Mathematics* (A)
Prereq.: 15.092
Year: G (2) 3–0–6
Discussion of current literature in the field with the purpose of reviewing and building upon the basic material covered in 15.091 and 15.092. Emphasis on mathematical techniques applicable in interdisciplinary theses and other studies and their applications in fields of interest to management. (*Restricted to doctoral candidates in the Sloan School of Management.*) *Staff*

15.10 *Quantitative Methods in Management*
Prereq.: 15.05, 18.10 or 18.034
Year: U (1) 3–0–6
Mathematical models and methods appropriate to the analysis of management problems. Emphasis on deterministic models. Formulation and solution of mathematical programming problems. *Kaufman*

15.11 *Introduction to Industrial Management*
Prereq.: ——
Year: U (1, 2) 3–0–6
Basic treatment of fundamental principles and general practices of industrial management. Specific coverage of selected important facets of marketing, finance, production, accounting, and managerial psychology. Information and procedures utilized in managerial decision making. Relationship of scientist and engineer to functions and decisions of management and the management of research and development. (*Not open to Course* XV *students.*) ——

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*

15.181 *Management Information and Controls*
Prereq.: ——
Year: G (S) 3–0–6
Theory and techniques underlying the generation of information measuring results of managerial efforts and the uses of such information for financial reporting, evaluation of alternative courses of action, motivation of efficient behavior, control, and managerial decision making. Application of theory to project analyses, transfer pricing, and issues arising out of decentralized structures. (*Restricted to Sloan Fellows.*) ——

15.182 *Quantitative Methods*
Prereq.: ——
Year: G (S) 3–0–6
Mathematical and statistical tools necessary for modern managerial analysis. Introduction of fundamental theories underlying various techniques recently developed to facilitate managerial decision making under uncertainty. Emphasis on the role and evaluation of modern quantitative techniques rather than technical expertise. (*Restricted to Sloan Fellows.*) *Crowston*

15.183 *Readings in Power and Responsibility* (A)
Prereq.: ——
Year: G (1, 2) 3–0–6
Detailed examination of major historical ideas affecting American industrial philosophy and processes. (*Restricted to Sloan Fellows.*) ——

15.184 *Structure of American Law*
Prereq.: ——
Year: G (S) 3–0–6
Analysis of the American legal system as a process for ordering our society. Consideration of selected legal problems to reveal the operation of the major component elements of the system: the judicial, legislative, administrative and private law-making power. Consideration of substantive law primarily from the standpoint of the process for generating and modifying legal policy. Emphasis on the problems of the law of business institutions. Extensive reading of case law as well as textual materials and legal essays. Research projects involving use of a law library. (*Restricted to Sloan Fellows.*) *Jacks, Nyhart*

15.185 *Operations Management* (A)
Prereq.: 15.181, 15.182
Year: G (1) 3–0–6
Theoretical approaches to problems faced by an operating manager. Introduction of philosophy and methodology of industrial dynamics in context of over-all systems description and improvement. Introduction of such techniques as mathematical and heuristic programming as aids to individual decision making within complex systems. (*Restricted to Sloan Fellows.*) *Crowston, Roberts*

15.186 *Marketing* (A)
Prereq.: 15.181, 15.182
Year: G (1) 3–0–6
Structure of consumer and industrial demand. Study of problems of achieving suitable distribution within the perspective of total promotional problem. Intensive study of several marketing management problems, such as formation of sound product policy, evaluation of promotion programs, and determination of market potentials. (*Restricted to Sloan Fellows.*) *Staff*

15.201 *Problems in American Political Economy*
Prereq.: ——
Year: G (1, 2) 3–0–6
Examination of the roles which governments have played in the development of the American economy. Attention focused on the function of politics and law, and of the different branches of government, in reconciling conflicting demands of social groups. (*Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.*) *Travis, Brower*

15.221 ***International Business Management I*** **(A)**
Prereq.: 15.014
Year: G (1) 3–0–6
Theory of, and institutional restraints acting on, international business, with emphasis on the pressure to effect harmonization of a firm's objectives with those of foreign business associate or customer, host government, and parent government. Discussion of historical flows of trade and investment and the impact of such flows on host and parent societies, followed by coverage of institutional restraints in the legal, informational, financial, and commercial areas. Specific problem areas dealt with: sources of foreign market information and evaluation of same, conflict of law regarding property and rights of aliens, taxation of international income, antitrust law, adjudication of international business disputes, investment guarantees, international banking operations, foreign exchange controls, financing of foreign trade, trade agreements and trading areas, international shipping and communications. Term project: an analysis of a foreign market for a specified product and firm.
Robinson

15.222 ***International Business Management II*** **(A)**
Prereq.: 15.221
Year: G (2) 3–0–6
In-depth examination of two or three foreign environments and familiarization with several important analytical constructs relevant to their understanding, followed by focus on characteristic organizational and operational problems arising from the international nature of the firm. Specific problem areas: development of an international business structure, selection of the appropriate form of international business relationship, communication across national cultural frontiers, selection of management personnel, management of labor-management relations under diverse circumstances, impact of different factor mixes on production, reduction of financial risk, development of an optimum control system. Term project: a role-playing game calling for design of the legal, administrative, and control structure of an internationalizing firm. *Robinson*

15.223 ***Industrial Structure of Europe*** **(A)**
Prereq.: 15.014
Year: G (1) 3–0–6
Seminar beginning with series of discussions led by faculty members and guests on those dimensions of the European environment relevant to the structure of contemporary European industry — e.g., historical, social-psychological, economic, political, and institutional. Special sessions devoted to the EEC, EFTA, OECD, NATO, banking, labor organizations, national efforts toward industrial consolidation and development, and pressures toward intra-European industrial integration. Latter part of seminar focusing on three industries (tentatively selected for 1968): construction, aircraft, and food products. Assignment of students in groups to report on one industry; industry members invited to respond. *Robinson*

15.232 ***Development Finance*** **(A)**
Prereq.: 15.012
Year: G (2) 3–0–6
Financing private and public enterprise in the developing countries: problems, institutional framework, and accompanying theory. The role and functions of capital market, international and local development finance institutions in enlarging financial flows to the developing world. Structure and management problems of development banking: procedures, organization, ownership, project evaluation, project financing, performance measurement.
Nyhart

15.31 ***Statistics for Behavioral Science***
Prereq.: ——
Year: U (1, 2) 3–0–6
The tools required for proper treatment of behavioral science research data. Descriptive and inductive statistics. Introduction of parametric and non-parametric techniques for the analysis of data. Fundamentals of measurement theory as a basis for determining the applicability of alternate techniques for data analysis. *Staff*

15.312 ***Labor-Management Relations***
Prereq.: ——
Year: G (1, 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. Public policy in labor-management relations. (*Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.*) *D. V. Brown*

15.32 ***Social Psychology***
Prereq.: 15.06
Year: U (2) 3–0–6
Cognitive processes such as learning, perception, and problem solving as individual phenomena and within the social context. Detailed examination of basic social psychological concepts such as influence, attitudes, communication, conflict, and interpersonal relations to provide understanding of the dynamics of group behavior. Provision of conceptual tools for application in the study of human behavior in organizations. *Farris*

15.322 ***Problems in Personnel Administration and Labor Relations*** **(A)**
Prereq.: 15.312
Year: G (2) 3–0–6
Managerial philosophy and management organization for personnel administration. Additional topics: the impact of unions on the personnel/industrial relations function; manpower planning and personnel budgeting; recruitment, selection and placement; labor turnover; performance appraisal; promotion and transfer; training and development; wage and salary administration; wage supplements and methods of wage payment; psychological research on pay; and personnel problems under the impact of technological change. Field studies on selected topics. *Haire*

15.33 ***Complex Organizations***
Prereq.: 15.32
Year: U (1) 3–0–6
Patterns of authority and control, socialization processes, member reference, group orientations (cosmopolitan vs. local), decision making structures, methods of conflict resolution as essential elements in any organization. Examination and comparison of different forms of organization (e.g., manufacturing companies, administrative agencies, research laboratories, hospitals) within the framework of these factors in terms of their implications for various dimensions of organizational performance (e.g., productivity, innovation and creativity).

15.331 ***Psychology and Human Organization***
Prereq.: ——
Year: G (1, 2) 3–0–6
Opportunity for the student to become familiar with the methods, subject matter, and findings of social psychology, 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

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relevant to the problems of industrial management, with class discussions and reading on such subjects as motivation, learning and behavior change, leadership. *(Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.)* *Staff*

15.332 *Advanced Seminar in Social Psychology* (A)
Prereq.: 15.331
Year: G (2) 3–0–6
More intensive coverage of the topics covered in 15.331. Detailed examination of basic social psychological factors such as power, communication, conflict, change, and interpersonal and group relations. Students will be expected to formulate research projects. *(Restricted to Ph.D. candidates in the Sloan School of Management, others admitted only by permission of instructor.)* *Haire*

15.333 *Seminar on Influence, Attitude Change and Adult Socialization* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Seminar for advanced Master's and doctoral students in organization studies, covering organization influences on attitudes and values, the development of occupational identity, and models of attitude change. Emphasis on gathering data and student research projects. *Schein*

15.334T *Practicum in Organization Development* (A)
Prereq.: 15.373
Year: G (1) 3–0–6
An intensive examination of organization development methods such as laboratory training, action research, grid organization development, job enlargement and organization design. Case analysis of the application of these methods to educational, governmental and industrial organizations. Use of previous summer work placements in organization development departments as a foundation for developing organization development skills. Integral part of specialization in organization development for Master's candidates, together with 15.331, 15.373, and a thesis on organization development. *(Admission by permission of instructor. Limited to students who have participated in previous supervised summer work placement in organization development.)* *Kolb*

15.335 *Personality Theory and Assessment* (A)
Prereq.: 15.334T
Year: G (2) 3–0–6
Application of psychological theory and method to understanding individual personality. Development of clinical skills through intensive analysis of live subjects and case studies. *(Enrollment limited to ten students; admission by permission of instructor.)* *Kolb*

15.339 *Seminar in Behavioral Sciences* (A)
Prereq.: 15.331
Year: G (2) 3–0–6
Development of basic concepts for understanding organizational behavior through critical analysis of important works in the field. Areas covered: motivation, perception, personality, learning, problem solving, decision making, group dynamics, organization theory, organizational development, and conflict resolution. *(Restricted to doctoral candidates in the Sloan School of Management.)* *Haire*

15.34 *Interpersonal Dynamics Laboratory*
Prereq.: 15.06
Year: U (1) 0–3–3
Opportunity to study human behavior through observation in interpersonal relationships that develop within an unstructured learning group. Readings in interpersonal behavior and nature of human relationships with particular focus upon the factors that influence effective performance within groups. *Staff*

15.35 *Behavioral Science Research Methods*
Prereq.: 15.31, *15.33, 15.34*
Year: U (1) 3–0–9
Introduction to methods of behavioral science research. General strategy of behavioral research (systematic vs. impressionistic investigation, hypothesis formulation, the probabilistic nature of data, etc.): research design (purposes, variance control, control of extraneous variables, use of control groups, randomized designs, factorial designs, two-group, multigroup and correlated-groups designs). Specific technologies of various designs (questionnaire construction, sampling, interviews, systematic observation). Theory and research findings. Organization of research project. *Staff*

15.351 *Industrial Sociology* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Examination of some sociological problems of industrial organizations: technological change and organizational specialists; professionalization of management; relations of industry to community and society. Field studies, secondary analysis of survey data, and library research on selected problems. ——

15.36 *Behavior Science Research Practicum*
Prereq.: 15.35
Year: U (2) 6–0–12
Development and completion of research project planned in 15.35 during previous term. Interpretation and application of research findings in management environment. Experimentation with such techniques as field survey work, laboratory experimentation, computer simulation, field consulting relationships. *(Restricted to undergraduates in the Sloan School of Management who are in the Behavioral Science Program.)* *Staff*

15.371 *Comparative Analysis of Organizations* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Comparative analysis of the structure and functioning of different types of organization: manufacturing organizations, research laboratories, schools, hospitals, armies, courts, administrative agencies, occupational associations, etc. Review of social science literature on organizations with special attention to problems of authority structures, management succession, and inter-organizational relations. Integral part of specialization in organization theory and research for Master's candidates, together with 15.373, 15.374, 15.381 and a thesis on organization theory and research. ——

15.372 *Organizational Psychology* (A)
Prereq.: 15.184
Year: G (1, 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.)* *Beckhard, Haire, Schein*

15.373 *Seminar on Organization Change* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
The processes of deliberate organizational change: the "change-agent" and "client-systems," criteria for and of effective change programs, strategic variables effected in change (e.g., power, communication, conflict), and technologies for producing change (e.g., consulting, training, research). Integral part of specialization in organization theory and research for Master's candidates, together with 15.371, 15.374, 15.381, and a thesis on organization theory. *(Enrollment limited to 15 students; admission by permission of instructor.)* *Beckhard*

15.374 *Organization* (A)
Prereq.: 15.331
Year: G (1) 3–0–6
Study of organizational theory as it applies to actual organizational behavior. Specific examples of organizational behavior problems analyzed at policy level: how policy, explicit and implicit, affects behavior in the total organization. Discussion of selected organization research studies, papers, cases. (*Enrollment limited to 20 students; admission only by permission of instructor.*) *Gil*

15.375 *Behavioral Theories of the Firm* (A)
Prereq.: 15.374
Year: G (2) 3–0–6
Research seminar for students of organizational behavior. Study of a small number of researchable topics in that area. Derivation of a model and set of operational hypotheses for describing and explaining each type of behavior. Design and planning of a research project to test a subset of these hypotheses. Discussion, critique, and aid of seminar members' own dissertation research plans, time and mutual interests permitting. Integral part of specialization in organization theory for Master's candidates, together with 15.371, 15.373, 15.381, and a thesis in organization theory. (*Primarily for doctoral candidates; others admitted by permission of instructor. Not offered 1968–69.*)

15.376 *Surveys and Experiments on Organizations* (A)
Prereq.: 15.331
Year: G (2) 3–0–6
Review of methodological problems of designing sample surveys, laboratory experiments, and field experiments. Introduction to problems of experimental design and techniques for analyzing data. Analysis of the nature of organizational experiments and the interplay between surveys, laboratory experiments, and field experiments. Practice in designing and conducting surveys and experiments on organizational problems. (*Enrollment limited to 16 students; admission by permission of instructor.*) *Sirota*

15.377 *Mathematical Behavioral Science* (A)
Prereq.: 15.012 15.092, 15.331
Year: G (2) 3–0–6
Subject designed to develop a student's capability in applying mathematical techniques to behavioral science research problems. Use of research literature relating to the particular technique being discussed. Emphasis on understanding the heuristics for applying and the implicit assumptions underlying each mode of mathematical expression. Relevant theorems derived and illustrated only to the extent necessary for analysis. Applications of analytical techniques to include: game theory, information theory, selected stochastic models, linear dynamics, analysis of general functional forms, structure of mathematical programs, discrimination functions, and complex determinate systems. (*Primarily for doctoral candidates; others admitted by permission of instructor.*

15.38 *Administrative Theory and Practice*
Prereq.: 15.71T
Year: U (1) 3–0–6
Organizational and operational problems of administration. Typical areas include productivity and morale, manager development, personnel management. Readings, case analyses, term papers, and outside speakers where appropriate. *L. B. Moore*

15.381 *Administrative Theory and Practice* (A)
Prereq.: 15.312, 15.412, 15.712, 15.812
Year: G (1) 3–0–6
Selected significant administrative areas with emphasis upon organization and its operational problems. Comparative study of current practice and relevant research findings. Typical areas include productivity and morale, manager development, personnel practices, communication, appraisal, motivation and performance, ethics and morality. Readings, case problems, term papers, and outside speakers where appropriate. Integral part of specialization in organization theory and research for Master's candidates, together with 15.371, 15.373, 15.374 and a thesis on organization theory and research.
L. B. Moore

15.382 *Management of Industrial Change* (A)
Prereq.: 15.331
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. Use of the conference as an improvement tool. Field work in comparative analysis of representative improvement programs. *L. B. Moore*

15.383 *Seminar in Managerial Behavior* (A)
Prereq.: 15.333 or 15.373; 15.374
Year: G (2) 2–0–7
Independent study and reports by individual students (or teams of students) within the field of the social psychology of managerial behavior. (*Admission by permission of instructor.*) *Beckhard*

15.384 *Research Management* (A)
Prereq.: 15.331
Year: G (2) 2–0–7
Lectures and discussion on topics ranging from the performance of individual scientists and engineers to the organization and management of research and development groups and laboratories, and the impact of research and development on the national economy. Integral part of specialization in organization for innovation for Master's candidates, together with 15.386, 15.387, and a thesis on research and development management. (*Primarily for Sloan School of Management graduate students, others admitted by permission of instructor.*) *Marquis*

15.385 *Managerial Communication* (A)
Prereq.: 15.372
Year: G (2) 3–0–6
Managerial communication considered in the organization setting and as a function of motivation. The communication process, media, and technique employed by the manager. Selected managerial problem areas in individual and group relations. (*Restricted to Sloan Fellows.*) *L. B. Moore*

15.386 *Seminar on Management Problems in Science and Technology* (A)
Prereq.: 15.384
Year: G (1, 2) 2–0–7
Discussions of problems and current research in the management of science and technology. Weekly seminars led by members of the faculty and invited speakers. Independent study and preparation of reports by individual students or teams of students. Integral part of specialization in organization for innovation for Master's candidates, together with 15.384, 15.387, and a thesis on research and development management. *Staff*

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15.387 ***Seminar on Communication Problems in Science and Technology*** **(A)**
Prereq.: 15.331
Year: G (1) 3–0–6
Utilization of scientific and technological information by research and development "problem solvers." Nature of the flow of information in science and technology. The "publication explosion" and the system's response to it. Role of the professional societies in dissemination of information. Impact of bureaucratic organization on flow of information. Problems of information flow between science and technology. Transfer of technology among nations. Integral part of specialization in organization for innovation for Master's candidates, together with 15.384, 15.386, and a thesis on research and development managment. *Allen*

15.391 ***Doctoral Seminar in Organization Studies I*** **(A)**
Prereq.: ——
Year: G (1, 2) 2–0–7

15.392 ***Doctoral Seminar in Organization Studies II*** **(A)**
Prereq.: 15.391
Year: G (1, 2) 2–0–7
Seminar covering the basic fields of social psychology, individual psychology, and sociology for purposes of preparing the doctoral candidate for his doctoral examinations. Basic concepts, theories, and research methods serving as focus for the seminar. (*Restricted to doctoral candidates.*) *Schein*

15.393 ***Doctoral Seminar on Career Development and Adult Socialization*** **(A)**
Prereq.: 15.333
Year: G (2) 2–0–7
Seminar for doctoral students in organization studies, covering the topics of career choice, career paths in organizations, career crises, personal changes induced by occupational career, and organizational factors such as recruitment, training, and management development. Emphasis on research and theory. (*Admission by permission of instructor.*) *Schein*

15.41 ***Financial Management***
Prereq.: 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. *Cootner*

15.412 ***Financial Management***
Prereq.: 15.501
Year: G (2) 3–0–6
Analysis of financial decisions central to firm's choice of assets. Central question of what assets to acquire and how to finance them covered under the following areas: forecasting the need for funds and techniques of cash budgeting; analysis of volume of short-term assets and sources of short-term funds; evaluating investment projects and programs and their financing; determinants of internally generated funds; analysis of securities and the capital markets. (*Primarily for Sloan School of Management graduate students; others admitted only by permission of instructor.*) *Cootner*

15.432 ***Capital Markets and Financial Institutions*** **(A)**
Prereq.: 15.412
Year: G (2) 3–0–6
The role and functioning of the capital and money markets as a device for the allocation of resources, the channeling of investable funds, and the reallocation of risk; financial institutions operating in these markets, principles governing the management of their assets and liabilities. *Modigliani*

15.452 ***Taxation and Business Management*** **(A)**
Prereq.: 15.412
Year: G (1) 3–0–6
Analysis of effect of taxation on conduct of business. Concentration on major decisions in which taxes impinge on the firm or its managers; concern with both theory and relevant empirical evidence. Topics covered: the "double-taxation" of dividends; the effect of capital gains taxation on the flow of capital and labor to business; incentives for investment; compensation planning; the effect of taxation on effort; alternatives to income taxation. *D. M. Holland*

15.46 ***Financial Administration of Industry*** **(A)**
Prereq.: 15.412
Year: G (1) 3–0–6
Analysis of specific financial problems confronting business managers. Emphasis on the analysis and development of criteria and models for financial decision making under conditions of uncertainty. *Pogue*

15.472 ***Risk and Uncertainty in Financial Decision-Making*** **(A)**
Prereq.: 15.092 or 15.591; 15.412
Year: G (2) 3–0–6
The decision making process under uncertainty from the point of view of both the industrial executive and the officers of financial institutions. The nature of financial markets with imperfect knowledge and the implications for investor behavior. The techniques available to the financial manager for the reduction and specialization of risk. The nature and formation of expectations about the future under conditions of uncertainty. Emphasis on principles and methods rather than results. *Cootner*

15.483J ***Flight Transportation*** **(A)**
(Same subject as 1.221J, 16.751J)
Prereq.: 15.412; 15.591 or 16.30
Year: G (1) 3–0–6
Integrated discussion covering basic concepts and operational characteristics of flight transportation systems. Methods of predicting vehicle performance, anticipating future design trends, and determining direct operating cost, airport design and functional layout; guidance and control techniques, both in terminal area and en route, communication and radar system performance.
S. Myers, Bone, R. H. Miller

15.484J ***Flight Transportation Seminar***
(Same subject as 1.222J, 16.752J)
Prereq.: ——
Year: G (1) 1–0–2
Economics of airline operation, problems of financing and of domestic and international route allocation. Subject developed around seminars presented by speakers from the regulatory agencies, national and international organizations and industry on particular phases of flight transportation. Preparatory lecture preceding each seminar. Opportunity for students to conduct studies in their area of major specialization on a particular topic covered by the subject. *S. Myers, Bone, Browne*

15.50 *Managerial Accounting*
Prereq.: ——
Year: U (1, 2) 3–0–6
Introduction to basic concepts and techniques of collecting, processing, and reporting information generated by business activities. Some attention to theory and methods of measurement of income and wealth; extensive coverage of financial analysis for decision making. *Goetz*

15.501 *Managerial Accounting*
Prereq.: ——
Year: G (1) 3–0–6
More intensive coverage of subject matter embraced by 15.50. (*Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.*)
Rockart, Sahin

15.503 *Managerial Accounting* (A, except XV)
Prereq.: ——
Year: G (2) 3–0–6
More intensive coverage of subject matter embraced by 15.50. *M. H. Kennedy*

15.51 *Managerial Information and Control*
Prereq.: 15.50 or 15.53
Year: U (2) 3–0–6
Consideration of issues involved in the use of control systems as an effective management tool and in building a framework useful in the design and evaluation of management control systems. Critical evaluation of uses and limitations of various forms of management control systems presently used by companies. Systems involving budgeting, profit planning and use of investment or profit centers. Examination of several issues bearing on management control systems, including program planning and budgeting, management information systems, long range planning and experience with Soviet control systems. Case materials from a variety of organizational settings to supplement readings. *Morton*

15.511 *Managerial Information and Control* (A)
Prereq.: 15.501 or 15.503
Year: G (1, 2) 3–0–6
More intensive coverage of subject matter embraced by 15.51. *Morton*

15.512 *Advanced Concepts in Managerial Information for Planning and Control* (A)
Prereq.: 15.012; 15.501 or 15.503
Year: G (2) 3–0–6
Analysis of alternative theories of the firm and managerial behavior. The various concepts of control and their implications. Measurements, information systems and the managerial planning and control process. The planning of the organization structure of the firm, the process of transformation of objectives and the theory of centralization and decentralization. Planning and control of semidecentralized operations. Problems encountered in the design of information and control systems. Concepts of integrated information systems, functional systems and associative-adaptive systems for over-all managerial planning and control. *Zannetos*

15.522 *Financial Accounting Problems* (A)
Prereq.: 15.412
Year: G (2) 3–0–6
Financial accounting theory and practice with particular attention to controversial problems in the measurement and reporting of corporate income and wealth. (*Alternate years.*) *T. M. Hill, Morton*

15.53 *Introduction to Managerial Information and Control Systems*
Prereq.: 1.00 or 6.47; 15.05
Year: U (1) 3–0–6
Information and control systems for decision making and implementation in financial, marketing, and production management. Uses and limitations of existing business systems with emphasis on managerial accounting. (*Not open to students who have taken 15.50.*) *Sahin*

15.531 *Control Processes and Systems* (A)
Prereq.: 15.501 or 15.503
Year: G (1) 3–0–6
Examination of various control concepts and systems, such as engineering, biological and social, and their implications for management sciences. Attempt to unify these concepts as a first step toward the evolution of a unified theory of managerial control systems. Class participation and individual exploration of ideas.
Zannetos

15.54 *Management Information Technology*
Prereq.: 15.05
Year: U (1, 2) 3–0–6
Introduction to basic computer technology. Formulation of procedures for use in a computer. Data representation and coding. Laboratory experience in machine language programming. Survey of computer hardware. Assemblers, computers, loaders, etc. Higher level languages. *Gorry*

15.541 *Management Information Technology* (A)
Prereq.: 15.50 or 15.501 or 15.503 or 15.53
Year: G (1, 2) 3–0–6
More intensive coverage of subject matter in 15.54.
Gorry

15.542 *Management Information Systems* (A)
Prereq.: 15.541, 15.712, 15.812
Year: G (1, 2) 3–0–6
Managerial applications of digital computers. Emphasis on the use of computers in integrated information and decision systems. Topics covered include information-based theories of management, a brief survey of information technology, the cost and value of information, techniques of system analysis and design, organizational implications of information technology. Lectures, case studies, programming project, and field studies.
Morton, Rockart

15.555 *Advanced Computer Systems* (A)
Prereq.: 6.251 or 15.542
Year: G (1, 2) 2–0–7
Seminar in advanced computer systems. Topics of current faculty interest, such as operating systems, time sharing, multiprocessing and multiprogramming.
Gorry, Ness

15.56 *Management Science Field Study*
Prereq.: *14.371*, 6.28, 15.10
Year: U (1) 4–0–8
Problems of practical application of management science techniques. Review of pertinent literature, field work, and case studies. Consideration of organizational, data, computational and dynamic aspects of automatic decision systems in production, marketing, and financial areas. *Carroll, Kaufman, Little*

15.565 *Seminar in Information and Control Systems* (A)
Prereq.: 15.331, 15.512, 15.542
Year: G (2) 2–0–7
Advanced treatment of various topics in the area of sophisticated information and control systems. Presentation and study of the result of on-going research of faculty and students. (*Primarily for doctoral candidates and other advanced graduate students.*) *Zannetos*

(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.

15.571 ***Feedback Dynamics Laboratory***
Prereq.: ——
Year: U (1, 2) 2–6–4
Laboratory experience with the dynamics and stability of feedback systems. Emphasis on feedback loops using physical equipment but including model experimentation in the form of analog and digital simulation and group role-playing simulation of feedback behavior in economic and management systems. Student design of laboratory experiments to illustrate system dynamic behavior. Readings and discussion stressing the generality of feedback processes as concepts unifying the physical sciences, engineering, the social sciences, and management. (*Open to students in the Dynamics of Management Systems Program in Course* XV. *Others by permission as resources permit.*)
Forrester

15.572 ***Principles of Systems***
Prereq.: 15.571, 18.034
Year: U (1, 2) 3–0–6
Principles of system structure and dynamic behavior. Similar to 15.573. Intended as a basis for the project work in 15.576. *Forrester*

15.573 ***Principles of Systems*** **(A)**
Prereq.: 18.034
Year: G (1, 2) 3–0–6
Principles of system structure and dynamics. Emphasis on managerial, economic, and social systems. Nonmathematical treatment of feedback loop behavior. Development of concepts that allow one to understand stability and growth processes extending to multiloop, non-linear systems. Aim of building an intuitive foundation as a basis for simulation studies of complex systems.
Forrester

15.574 ***System Mathematics***
Prereq.: 15.572, 18.034
Year: U (1, 2) 3–0–6
Mathematics of dynamic behavior in feedback systems. Similar to 15.575. *Pugh*

15.575 ***System Mathematics*** **(A)**
Prereq.: 18.034
Year: G (1, 2) 3–0–9
Development of dynamic system principles through analytic techniques. Review of linear differential equations. Frequency domain: Laplace and Fourier transforms, stability criteria, and root loci. Transfer functions and signal flow graphs. Relationship of component behavior to system behavior. *Pugh*

15.576 ***Industrial Dynamics I***
Prereq.: 15.572, *15.574*
Year: U (1, 2) 3–0–6
Similar to 15.58 but with more emphasis on projects for students who have completed 15.572. *Swanson*

15.577 ***Industrial Dynamics II***
Prereq.: 15.576
Year: U (1, 2) 3–0–6
Similar to 15.582. *Roberts*

15.578 ***Research Seminar in Dynamics of Management Systems I***
Prereq.: 15.577
Year: U (1) 3–0–6

15.579 ***Research Seminar in Dynamics of Management Systems II***
Prereq.: 15.578
Year: U (2) 3–0–6
Special research topics and papers relating to dynamics of management, economic, or social systems. Special emphasis on quality of writing. *Forrester, Roberts*

15.58 ***Industrial Dynamics***
Prereq.: ——
Year: U (1, 2) 3–0–6
Study of the firm as a complex system emphasizing the interactions between decision, actions, and information flows. Analysis of the dynamic behavior of firms by computer simulation with emphasis upon designing policies and information flow to generate more effective behavior. Treatment and analysis of the properties of complex feedback systems. Organizational control and the growth of a firm viewed as feedback processes. Discussion of the applications of industrial dynamics ideas in real situations. Student projects to analyze a situation using the concepts of industrial dynamics and computer simulation. *Swanson*

15.581 ***Industrial Dynamics I*** **(A)**
Prereq.: 15.012 or 18.034
Year: G (1, 2) 3–0–6
Policy formulation and managerial decisions treated from an over-all systems view; primary emphasis on interaction of separate elements of a firm, industry, or nation. Recognition of underlying structure of such organizations, including the flows of men, materials, money, capital equipment and orders, tied together by information flows used in the decision making network. Computer simulation of feedback models of such situations forms the basis of managerial policy experimentation. Treatment and analysis of the properties of complex feedback systems. Student projects to analyze a situation using the concepts of industrial dynamics and computer simulation. *Swanson*

15.582 ***Industrial Dynamics II*** **(A)**
Prereq.: 15.58 or 15.581
Year: G (1, 2) 3–0–6
Treatment of the process and problems of application and implementation of industrial dynamics. Class divided into teams, each studying the major systems problems of a cooperating organization. Goal of student effort: eventual implementation of policy changes in the organization. Study of previous and current industrial dynamics applications in industry and government. Discussion sessions with management consultants and operations research staff. Selected readings to help develop understanding of the implementation process. (*Enrollment limited, admission by permission of instructor.*) *E. B. Roberts*

15.587 ***Research Seminar in Dynamics of Management Systems I*** **(A)**
Prereq.: 15.58 or 15.581
Year: G (1, 2) *Arr.*

15.588 ***Research Seminar in Dynamics of Management Systems II*** **(A)**
Prereq.: 15.587
Year: G (1, 2) *Arr.*
Focus of each seminar on a theme within which student research will produce short papers chosen to fill gaps in literature of dynamics of social systems. High written quality as a goal aimed at occasional publication of collections of student papers. A research activity in itself or a companion to thesis or project research. (*Admission by permission of the instructor.*) *Forrester, Roberts*

15.591 ***Mathematical Programming I***
Prereq.: 18.034
Year: G (1, 2) 3–0–6
Linear programming. Systems of linear equations, simplex method, duality theory. Sensitivity analysis, geometric view of linear programming. Transportation and shortest route problems. Introduction to advanced topics such as integer programming and generalized programming. *J. F. Shapiro*

15.592 *Mathematical Programming II* (A)
Prereq.: 15.092 or 15.591
Year: G (2) 3–0–6
Non-linear programming. Topics include classical optimization methods, linear approximations, stochastic programming, Kuhn Tucker theory and quadratic programming, integer linear programming, branch and bound methods, gradient procedures, and dynamic programming. Emphasis on laying groundwork for practical computations. *J. F. Shapiro*

15.593 *Stochastic Systems* (A)
Prereq.: 6.28; 15.092 or 15.591
Year: G (1) 3–0–6
Birth and death processes, renewal theory, Markov chains, diffusion processes. A wide variety of applications in queuing theory. Additional applications in inventory, economic growth, and mathematical learning theory. *Staff*

15.597 *Bayesian Analysis Studies* (A)
Prereq.: 15.095
Year: G (1) 3–0–6
Primary emphasis on Bayesian methods in multivariate problems. Content varying from year to year. Typical topics: the multivariate normal distribution, best of several processes problem, stratified sampling, bias, extended natural conjugate analysis of the normal process, multiple regression, multivariate regression, simultaneous equation systems, Bayesian interpretation of standard multivariate inference statements. Term paper on selected multivariate statistical problems.
Kaufman

15.598 *Case Studies in Quantitative Analysis* (A)
Prereq.: 6.28; 15.092 or 15.591
Year: G (1) 3–0–6
Discussion of the successes and difficulties experienced in applying quantitative methods to management decision making in areas such as inventory and production control, scheduling, marketing strategy, research and development planning, equipment replacement and reliability control. Consideration of business, industrial, and military problems in terms of their basic elements. Case studies and field work. (*Not offered 1968–69.*)
Kaufman

15.599 *Research Seminar in Quantitative Analysis* (A)
Prereq.: ——
Year: G (1, 2) 2–0–7
Special topics in quantitative management forming the basis for student research. Review of technical literature, guest lectures, and general discussion. *Kaufman*

15.61 *American Legal System*
Prereq.: 14.01
Year: U (1, 2) 3–0–6
Analysis of the American legal system as a process for ordering our society. Consideration of selected legal problems to reveal the operation of the major component elements of the system: the judicial, legislative, administrative and private law-making power. Consideration of substantive law primarily from the standpoint of the process for generating and modifying legal policy. Emphasis on the problems of the law of business institutions. Extensive reading of case law as well as textual materials and legal essays. Research projects involving use of a law library. *Jacks*

15.65 *Labor Law*
Prereq.: 15.61
Year: U (1) 3–0–6
The legal structure of labor-management relations. Review of evolution of labor relations law in the twentieth century and intensive study of the current federal labor legislation. Among subject areas examined from the legal standpoint are the organization of labor, negotiation and administration of the collective agreement, the status of economic weapons (strikes, boycotts, lockouts, etc.), the relations between the individual and his union, and the role of federalism in the law of labor relations. Extensive use of case materials, including tape-recorded cases. *Jacks*

15.661 *American Legal System* (A)
Prereq.: 15.012
Year: G (1, 2) 3–0–6
More intensive coverage of subject matter covered in 15.61. *Jacks*

15.671J *Labor Economics* (A)
(Same subject as 14.671J)
Prereq.: 14.64 or 15.312
Year: G (2) 3–0–6
Primary emphasis on the determination of wage levels and wage differentials through an analysis of labor supply and labor demand, as affected by economic as well as by institutional factors. The impact of unions on both wage and non-wage elements of collective bargaining in the light of the characteristics and objectives of particular unions. Other special topics growing out of recent research in labor economics. (*Not offered 1968–69.*)
C. A. Myers

15.672J *Public Policy on Labor Relations* (A)
(Same subject as 14.672J)
Prereq.: 14.64 or 15.312
Year: G (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, Piore*

15.673 *Labor-Management Relations and Public Policy* (A)
Prereq.: 15.184
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.*) *Siegel, C. A. Myers*

15.674J *Comparative Industrial Relations Systems* (A)
(Same subject as 14.674J)
Prereq.: 14.64 or 15.312
Year: G (1 or 2) 3–0–6
International and comparative analysis of industrial relations problems and experience. (1) A review of traditional theories of the labor movement. (2) A survey of recent theorizing about management and labor problems in economic development. (3) Examination of selected issues involving interest groups and the strategies of economic development, including discussion of the nature and functions of labor and management organization in different contexts; the role of the state in establishing procedures and in shaping the substance of industrial relations; the participation of interest groups in the formulation of economic and social policy; manpower and economic growth; external influences on national industrial relations systems. *Siegel*

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15.691J ***Research Seminar in Industrial Relations*** **(A)**
(Same subject as 14.691J)
Prereq.: 15.671J or 15.672J
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.
Siegel, Haire

15.692J ***Research Seminar in Industrial Relations*** **(A)**
(Same subject as 14.692J)
Prereq.: 15.691J
Year: G (2) 3–0–6
Continuation of 15.691J. *Siegel, Haire*

15.70 ***Management Decisions I***
Prereq.: 15.05, 15.06, 15.10
Year: U (2) 3–0–6

15.71T ***Management Decisions II***
Prereq.: 15.70
Year: U (1) 3–0–6
Introduction to managerial decision problems in marketing, finance, and operations. The underlying determinants of consumer and industrial demand behavior. Policy considerations in selection and control of channels of distribution, product line, pricing and sales promotion. Analysis of financial decisions central to firm's choice of assets. Capital budgeting and investment evaluation; portfolio selection. Operations management problems including facilities layout, project management, plant scheduling, and production and inventory control. Emphasis on cases and analytical methods of approach. *Urban, Galbraith, S. C. Myers*

15.712 ***Operations Management*** **(A)**
Prereq.: 15.012, 15.092, 15.331
Year: G (1, 2) 3–0–6
Study of decision making techniques for the economic problems of operations management, including operations scheduling, inventory control and facilities design, with emphasis on problems of implementation. Examination of a wide variety of institutional settings, including factories, utilities, and government offices. Applied theory from prerequisite subjects including mathematical programming, simulation, statistical models and organizational design. *Crowston, Pierce*

15.73 ***Management Laboratory***
Prereq.: 14.01 or 15.71T
Year: U (1, 2) 3–3–3
Philosophy and methodology of industrial improvement. Application of tools and techniques of improvement to real problems in industry. Formation of a planned program for continued improvement within a company. Economic and human factors in the improvement process. Problems in management creativity. Laboratory experimentation. Participation in actual company situations. *Goodwin*

15.74 ***Advanced Management Laboratory***
Prereq.: 15.73
Year: U (2) 3–3–3
Organization and implementation of industrial improvement. Managerial procedures employed in introducing and developing a company improvement program with administrators, executives, and employees. Coordination of all improvement activities within the company. Involvement in an actual company program situation.
Goodwin

15.741 ***Advanced Management Laboratory*** **(A)**
Prereq.: 15.501
Year: G (1, 2) 3–3–3
Improvement as a management philosophy. Coordination of methods of analysis, design, measurement, and control of improvement activity. Critical analysis and various improvement techniques and methods of implementing improvement in industry. Involvement in actual industrial situations. *Goodwin*

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. *Crowston*

15.791 ***Operations Planning and Control Systems*** **(A)**
Prereq.: 15.712
Year: G (2) 3–0–6
Treatment of operations planning and control system design problems from the mathematical, economic, information, and operational points of view. Critical path methods and extensions. Job shop scheduling including underlying sequencing theory and research in heuristic methods. Flow shop control with emphasis on information systems aspects. Lectures, case studies, and term project. *Carroll, Pierce*

15.792 ***Manufacturing Decisions Seminar*** **(A)**
Prereq.: 15.712
Year: G (2) 3–0–6
Primary focus on the improvement of decision processes regulating the organization's operations. Design variables affecting the decision process: organizational structure, information system, decision programs and algorithms, and the reward-penalty system. Mutual interdependence of the four classes of design variables as they affect organizational performance; selection of appropriate combination of design variables to accomplish given tasks. *Galbraith*

15.81 ***Marketing***
Prereq.: 15.07
Year: U (1, 2) 3–0–6
Subject matter of 15.812 presented for undergraduates.
Urban

15.812 ***Marketing***
Prereq.: 15.091
Year: G (1, 2) 3–0–6
Analysis of the marketing environment of the firm and the firm's strategies with respect to marketing problems. Development of an understanding of the consumer based on behavioral science concepts. Study of marketing decision areas, including product planning, pricing, advertising, selling, promotion, distribution, and competitive strategies. Quantitative techniques and information system concepts presented as applicable. *(Restricted to Sloan School of Management graduate students; others admitted only by permission of instructor.)* *Urban*

15.821 ***Business Game*** **(A)**
Prereq.: 15.71T or 15.812
Year: G (1, 2) 3–0–6
Managerial decision making brought out through team participation in a complex computerized business game. Marketing planning, decision planning, decision making in product development, distribution channels, pricing, sales force, advertising, production and inventory control, and financial planning. Appreciation for interactions and the need for imaginative strategies and integrated policies. Emphasis on producing workable solutions to ill-structured problems by systematic problem definition, strategy formulation, data collection, and evaluation of alternatives. *Amstutz*

15.832 *Management Measurement and Information* (A)
Prereq.: 15.091
Year: G (2) 3–0–6
Focus upon management's need for non-accounting measurements and information from sources both internal and external to the organization. Analysis of secondary sources of information and methods for generating primary measurements, generally from human respondents. Development of scales of measurement and psychometric procedures. Sampling theory from both a classical and a Bayesian viewpoint. Non-parametric statistical procedures for analyzing measurements. Examples from all areas of management. *Montgomery*

15.852 *Marketing Models* (A)
Prereq.: 15.092, 15.812
Year: G (2) 3–0–6
Examination of the state of the art in marketing models with emphasis on recent advances. Topics include: new product planning models, adaptive control models, microanalytic simulation of competitive environments, stochastic models of consumer behavior, and on-line interactive use of models. Criticism in depth of a number of models and participation in model development project. *Montgomery, Urban*

15.891 *Research Seminar in Marketing* (A)
Prereq.: 15.812
Year: G (2) 3–0–6
Seminar on current marketing literature and current research interests of faculty and students. Topics such as the theory of consumer behavior, simulation of consumer product markets, marketing experimentation, and the development of behavioral models from consumer panel data. *Staff*

15.901 *Study and Research in Management System Dynamics*
Prereq.: ——
Year: U (1, 2) *Arr.*
Integrated program for juniors and seniors in the Sloan School of Management departing from the usual format of separate academic subjects in management and the engineering minor. Research and tutorial program in system dynamics supported by individual study of the normal functional subject matter in management. Research and guided study supervised by the staff of the school. (*Enrollment limited to ten students per class, admission only by permission of the systems curriculum committee of the Sloan School of Management.*) *Forrester*

15.921 *New Enterprises* (A)
Prereq.: 15.412, 15.501
Year: G (1) 2–0–7
Organization and management of technically based companies. Financing of new enterprises through private, corporate and public capital sources. The role of government and the impact of Federal R and D on corporate growth. Trends in science and technology in terms of business opportunities. Preparation of cases by study of the operations of local companies and detailed development of plans for launching of new business ventures. (*Enrollment limited to 15 students: admission by permission of instructor.*) *R. S. Morse*

15.93 *Business Practice and Policy Determination* (A)
Prereq.: 15.312, 15.412, 15.712, 15.812
Year: G (1, 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. ——

15.944 *Foreign Policy for Executives*
Prereq.: ——
Year: G (2) 3–0–6
Examination of significant problems of contemporary American foreign policy and international relations of particular concern to management. Special attention given to developments in communist countries, problems of the emerging nations, changes in Western Europe, issues of defense and arms control, and planning and administering foreign policy operations. (*Restricted to Sloan Fellows.*) ——

15.95 *Special Studies in Management*
Prereq.: ——
Year: U (1, 2) *Arr.*
Special tutorial arrangement with a faculty member for guided reading, research, laboratory, or teaching experience. *Staff*

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*

15.98 *Seminar in Administration* (A)
Prereq.: 15.181
Year: G (1) 3–0–6

15.99 *Seminar in Administration* (A)
Prereq.: 15.181
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.*) *Gil*

16.
Aeronautics and Astronautics

16.001 *Thermodynamics and Statistical Mechanics*
Prereq.: 8.02, 18.02
Year: U (2) 4–2–6
Introductory concepts and definitions. First and second laws of thermodynamics. Thermodynamic temperature, entropy, and availability, with application to flow processes and energy conversion. Statistical thermodynamics and chemical equilibrium. Properties of simple systems. *Wachman*

(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.

16.01 ***Dynamics***
Prereq.: 8.02, *18.034*
Year: U (1, 2) 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. *Potter, Wrigley*

16.02 ***Aerodynamics***
Prereq.: 16.001
Year: U (1, 2) 4–2–6
Introduction to the aerodynamics of flight vehicles. One-dimensional flow of a perfect gas, shock and expansion waves, converging-diverging nozzles, supersonic airfoils. Motion of fluid in three dimensions, conservation equations. Vorticity, Kelvin's theorem, Bernoulli's equation. Two-dimensional constant-density potential flows. Discussion of boundary layers and elementary viscous flows. Small perturbation theory, airfoils, and three-dimensional wings in subsonic and supersonic flow. *Covert*

16.03 ***Gasdynamics***
Prereq.: 16.001, 18.034
Year: U (1) 4–2–6
Introduction to continuum gasdynamics with emphasis on basic fluid mechanical phenomena. Kinetic theory foundations. Nature of fluids — kinetic and continuum pictures. Boltzmann equation and general conservation theorems. Navier-Stokes equations as continuum approximation. Momentum theorems. Kinematics of fluids. Kelvin's and related theorems. Dynamics and thermodynamics of compressible, rotational flows. Disturbances in gases at rest. Ackeret theory. Quasi-one-dimensional flows. Normal and oblique shocks. Prandtl-Meyer theory. Incompressible, inviscid flow theory. Elementary viscous flows. *McCune*

16.031 ***Topics in Fluid Mechanics***
Prereq.: 16.02 or 16.03
Year: U (2) 3–0–6
Application of potential theory to inviscid flow problems. Green's theorem and source, doublet, and vortex distributions. Application to thin wing problems. Two-dimensional thin airfoil theory. Prandtl lifting-line theory. Prandtl-Glauert transformation for subsonic flows. Unsteady potential flows, theory of acoustic disturbances. Application to supersonic airfoil problems. Application of Navier-Stokes equations to viscous fluid problems. Some exact solutions exhibiting boundary layer behavior. Derivation of boundary layer equations and certain classical results. Karman momentum integral equation and its use. Brief discussion of separation, transition and turbulence. *McCune*

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. *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
Dynamics of a perfect gas. Irrotational and rotational flows. Character and analysis of subsonic, transonic, supersonic, and hypersonic, inviscid, multidimensional flows. Similarity concepts, characteristics, approximation procedures, small disturbances, integral and numerical methods. Application to shock tubes, wings, blunt and slender bodies, blast waves. *Baron*

16.052 ***Topics in Gas Dynamics*** **(A)**
Prereq.: 16.051
Year: G (2) 3–0–9
Dynamics of a real gas. High-temperature flow of excited, chemically reacting, absorbing media. Non-equilibrium and relaxation phenomena, dispersion. Extension of similarity, characteristics, and shock concepts. Radiation coupled gas dynamics. Application to hypersonic test facilities, viscous layers, blunt bodies. *Baron*

16.065 ***Physics of High Speed Gas Flows*** **(A)**
Prereq.: 16.03, 18.06
Year: G (1) 3–0–9

16.066 ***Physics of High Speed Gas Flows*** **(A)**
Prereq.: 16.065
Year: G (2) 3–0–9
Elements of statistical mechanics and kinetic theory. Discussion of the Boltzmann equation and its integration to give the Navier-Stokes equations. Rarefied gas dynamics. Elements of quantum mechanics. Mechanisms of dissociation, ionization, radiation, and relaxation. Elements of electrodynamics of continuous media. The physics of a continuous medium in motion. *Trilling*

16.067 ***Gas-Surface Interactions*** **(A)**
Prereq.: 8.05 or 8.211
Year: G (1) 3–0–9
Discussion of behavior of a rarefied gas at a solid boundary in terms of processes occurring on collisions of gas molecules with the surface. Processes including reflection and diffraction of molecular beams, energy and momentum accommodation, and adsorbtion. Experimental and theoretical methods for treating accommodation coefficients and free molecule drag coefficients. Discussion of the origin of van der Waals forces and the application of Lennard-Jones potential to interface problems. *Wachman*

16.071 ***Aerodynamics of Wings and Bodies*** **(A)**
Prereq.: 16.03
Year: G (1) 3–0–9

16.072 ***Aerodynamics of Wings and Bodies*** **(A)**
Prereq.: 16.071
Year: G (2) 3–0–9
Coordinated presentation of theoretical methods useful for predicting performance and stability of thin lifting surfaces and slender vehicles in high-speed flight. Review of fluid mechanics, with emphasis on potential aerodynamics. Constant-density flow and procedures for indirectly introducing real-fluid effects. Application of the method of inner and outer solutions as a framework for analyzing cases such as the following: slender bodies or wing-body combinations, thin airfoils, and thin planar wings in subsonic and supersonic flight. Drag optimization techniques, non-planar lifting surfaces, flows with free vortices, transonic motion, unsteady flows, and other special topics selected in the light of currently important aeronautical problems. *Widnall*

16.09 ***Fields in Continuous Media***
Prereq.: 8.02, 18.02
Year: U (1, 2) 4–2–6
Definition of a continuous medium as an idealization of reality; kinematics, force and stresses; statement and

formulation of fundamental laws (conservation of mass and charge, Newton, Maxwell, first and second thermodynamics, gravitation, with couplings among them); constitutive and dissipative relations and their connection with experiment or the molecular world; initial and boundary conditions; discontinuities and interfaces. Numerous demonstrations and sample applications with special interest in aeronautics and astronautics to be carried out throughout the term; mathematical tools introduced or developed as needed. *Trilling, Covert*

16.105 *Applied Aerodynamics* (A)
Prereq.: 16.02, 16.11
Year: G (2) 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. *Larrabee*

16.11 *Aerodynamics of Flight Vehicles*
Prereq.: 16.02 or 16.03
Year: U (2) 3–0–6
Development and examination of the potential and viscous flow concepts useful in evaluating the aerodynamic loads on flight vehicles. Attention directed toward the validity and limitations of the concepts. Introduction to the mechanics of boundary layers and heat transfer. *Bicknell*

16.12 *Multivariable System Dynamics* (A)
Prereq.: 16.01
Year: G (2) 3–0–6
Case studies of multivariable dynamic systems ranging from traditional conservative mechanical vibrations, linear circuits, and feedback control systems to vehicle dynamics, optimization of non-linear systems, and optimal filtering. Treatment of sets of linear, variable-coefficient, differential equations using matrix and vector notations, adjoint functions, the state-space approach, and digital computation. *Halfman, Potter*

16.13 *Special Problems in Interplanetary Flight* (A)
Prereq.: 16.46 or 18.15
Year: G (2) 3–0–6
Applications of linear perturbation theory to the problems of mission planning, trajectory selection, navigation, and guidance for interplanetary flight. Emphasis on the physical interpretation of optimum, analytic solutions to these problems. Comparisons between accurate but complex mathematical models and approximate but simple models. Numerical examples based on manned missions to Venus and Mars. Analysis of ballistic as well as continuous-thrust trajectories. *Hollister, Stern*

16.15 *Advanced Flight Vehicle Stability and Control* (A)
Prereq.: 16.11
Year: G (1) 3–0–6
Analytic solutions for non-linear problems in flight mechanics. Linear approximations to flight vehicle dynamics, including: classical airplane stability theory, stability derivative estimation, dynamic similarity laws, gust response, inertial cross coupling and spinning. Dynamics of simple aircraft-controller combinations. Analysis of flight test dynamic stability data. *Larrabee*

16.20 *Solid Mechanics I*
Prereq.: 8.01, 18.02
Year: U (1, 2) 4–2–6
Fundamentals of solid mechanics. Principles of mechanics, vector properties of forces and moments, equilibrium of groups of particles. Statics, applications to trusses and beams, simple statically indeterminate structures. Concepts of strain and stress, with emphasis on tensor properties, transformation, principal axes. Stress equilibrium and strain compatibility. Stress-strain relations including anisotropy. Equations of elasticity, boundary conditions, applications to rods, beams, and plane stress. Introduction to plasticity. Bisplinghoff, Mar, Pian, *Statics of Deformable Solids*. *Bucciarelli*

16.201 *Solid Mechanics II*
Prereq.: 16.20
Year: U (1, 2) 4–0–6
Fundamentals of solid mechanics applied to analysis of flight vehicle structures. Plane stress, plane strain problems in curvilinear coordinates. Bending, shear, torsion of rods and thin wall beams. Introduction to energy principles and applications to statistically indeterminate structures. Buckling of columns and stability phenomena. Theories and modes of structural failure. *Mar, Tong*

16.21 *Plates, Stability and Thermoelasticity* (A)
Prereq.: 16.201
Year: G (1) 3–0–9
Analysis of thermal stress arising from supersonic and hypersonic flight. Analysis of homogeneous, orthotropic and stiffened plates. Stability theory applied to structural problems. *Tong*

16.22 *Shell Structures* (A)
Prereq.: 16.201
Year: G (1) 3–0–9

16.23 *Shell Structures* (A)
Prereq.: 16.22
Year: G (2) 3–0–9
Elements of tensor analysis. General formulation of elasticity in curvilinear coordinates. Introduction to differential geometry. Development of shell equations in tensor form. Membrane behavior of thin shells. Bending behavior of thin shells. Various topics such as shallow shells, shells of revolution, asymptotic integration, large deflections, buckling, and inflated shells. *Dugundji*

16.24 *Plasticity, Viscoelasticity and Creep* (A)
Prereq.: 16.201
Year: G (1) 3–0–9
Problems associated with viscoelastic and creep behavior of materials. Plastic and viscoelastic stress-strain relations. Discrete-element viscoelastic models, creep compliance and relaxation modulus. Linear viscoelastic stress analysis. Alfrey's theorem and its generalizations. Non-linear creep laws. Structural analyses in presence of creep. Creep buckling. Mechanical problems associated with solid propellants. Damping by means of viscoelastic materials. (*Not offered 1968–69.*) *Pian*

16.25 *Advanced Topics in Structural Mechanics* (A)
Prereq.: 16.201
Year: G (2) 3–0–9
Varying content. New methods and problems in the structural design and analysis of aerospace vehicles. *Mar*

16.26 *Solid Mechanics Laboratory* (A)
Prereq.: 16.62
Year: G (1 or 2) *Arr.*
Graduate laboratory subject in solid mechanics and experimental stress analysis, conducted as individual projects arranged between student and instructor. *Pian*

(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.

16.27 ***Variational and Matrix Methods of Structural Mechanics*** **(A)**
Prereq.: 16.201
Year: G (1) 3–0–9

16.28 ***Variational and Matrix Methods of Structural Mechanics*** **(A)**
Prereq.: 16.27
Year: G (2) 3–0–9

Structural analysis through the use of variational principles. Derivation of the governing differential equations. Principles of virtual work and complementary virtual work. Principles of stationary potential energy, stationary complementary energy, Reissner's principles and generalizations. Approximate solutions of solid continua and complex flight vehicle structures. Solutions by finite-element idealization and matrix structural methods. Finite difference methods. Inclusion of initial stresses, initial strains, non-uniform temperatures, small deflections, large deflections, elastic stability, plasticity and temperature-dependent behaviors. *Pian*

16.30 ***Principles of Automatic Control***
Prereq.: 6.14, 16.01
Year: U (1, 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, Whitaker

16.31 ***Principles of Instrumentation and Control*** **(A)**
Prereq.: 16.30
Year: G (1) 3–0–9

Generalized concept of system design and synthesis with consideration of intercoupled relationships among multiple inputs and outputs, practical limitations of physical components to satisfy the static and dynamic specifications of system response to control inputs and disturbing inputs, and the adaptation to parameter variations. Use of analog and digital computers as design tools. Principles of random processes and optimum linear system design for random inputs. Sampled data system analysis and the design of on-line digital controllers. *Li, Meiry*

16.32 ***Principles of Instrumentation and Control*** **(A)**
Prereq.: 16.31
Year: G (2) 3–0–9

Brief treatment of time-varying linear control systems. General treatment of the principles of analysis and design of feedback control systems incorporating non-linear components. Extensive treatment of the multiple-input describing function method as applied to stability analysis, steady-state response to forcing functions and transient response. Introduction of modern control theory for the determination of control logic for optimum transient response with discrete or continuous signals in open and closed loop configurations. Brief discussion of optimum filtering estimation and identification concepts.
Li, Vander Velde

16.33 ***Automatic Control System Laboratory*** **(A)**
Prereq.: 16.30
Year: G (1) 2–2–6

Study of open loop and closed loop characteristics of feedback control systems. Experimental verification of various compensation schemes designed with root-locus and phase-gain diagram techniques. Exploitation of the particular properties of electrical, hydraulic, and pneumatic drive systems. Study of a non-linear adaptive control system and an optimum switching control system. Case experiments include the Apollo IMU control system, delta-modulated instruments and statistical identification techniques. Use of a hybrid computer in control applications emphasized. *Meiry*

16.34T ***Automatic Control of Flight Vehicles*** **(A)**
Prereq.: 16.30
Year: G (2) 3–0–9

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. (*16.15 recommended as preparation.*) *Whitaker*

16.35 ***Special Problems in Instrumentation Control and Guidance*** **(A)**
Prereq.: 16.30
Year: G (1 or 2) *Arr.*

Problems of interest to qualified individual students in consultation with the instructor. *Staff*

16.36 ***Comparative Instrumentation*** **(A)**
Prereq.: 16.30
Year: G (2) 3–0–6

Generalized fundamental treatment directed toward planning of measuring systems. Analysis of measurement concepts, components, system configurations and test methods with emphasis on comparison between different techniques. Detailed examination and error analysis of important classes of practical instruments stressing the general techniques used to improve accuracy. Students may also elect 16.361, an associated laboratory subject. *L. R. Young*

16.361 ***Comparative Instrumentation Laboratory*** **(A)**
Prereq.: 16.30
Year: G (2) 0–2–1

Individual laboratory projects for detailed investigation of one phase of instrument accuracy, emphasizing current research and development. (*Restricted to students taking 16.36.*) *L. R. Young*

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 system engineers. Review of probability theory with application to such problems as system reliability and multidimensional random errors. Measurement of the statistics of random variables and processes. Extensive treatment of random processes in linear systems using both transfer function and state space descriptions. Design of optimum filters according to Wiener and Kalman. *Vander Velde*

16.371 ***Estimation and Control of Stochastic Processes*** **(A)**
Prereq.: 16.37
Year: G (2) 3–0–9

Study of methods of estimation and control of stochastic processes. Prediction, filtering and smoothing for nonstationary systems. Brownian motion, Markov processes and the Fokker-Planck-Kolmogorov equations. Optimal control in the presence of system process and measurement disturbances. Applications to the control and guidance of spacecraft. *Deyst*

16.38 *Physical Components of Control Systems* (A)
Prereq.: 6.14
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 *Applied Optimal Control* (A)
Prereq.: 16.31
Year: G (2) 3–2–6
Design of optimal and near-optimal controls and systems emphasizing various analytic measures of performance, and computer techniques for the solution of complex problems. Optimization of system parameters and the determination of optimal control or feedback gain histories are treated using both deterministic and stochastic performance measures. Exercises in system design are carried out by the class using analog and digital computers. *Vander Velde*

16.40 *Principles of Flight Guidance*
Prereq.: 16.30
Year: U (1) 3–0–9
Guidance requirements for representative space and atmospheric flight missions analyzed in terms of mission phases, navigation, flight path corrections and steering laws. Implementation of guidance systems using celestial, inertial, and radio techniques in conjunction with data processing. Examples include air traffic control and a complete manned space flight. *Hollister*

16.41 *Space Dynamics and Gyroscopic Instruments* (A)
Prereq.: 16.01
Year: G (1) 4–0–8
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, Hollister

16.42 *Inertial Guidance* (A)
Prereq.: 16.30, 16.41
Year: G (2) 4–0–8
Principles of design of inertial navigation systems, starting from dynamics of measurement components and kinematics of system behavior. Methods of mechanizing equations of motion of physical pendulum and gyro compass. Inertial navigation systems for space close to earth and marine use. Characteristics of five-gimbal, three-gimbal and gimballess systems. Mechanization of a satellite navigator. Question of extension to interplanetary regions. *Markey, Wrigley*

16.43J *Life Support and Human Performance in Manned Systems* (A)
(Same subject as 2.181J)
Prereq.: 2.14 or 16.30
Year: G (2) 3–3–6
Environmental control and physiological characteristics of man as related to unusual acceleration, thermal, atmospheric or other stresses. Advanced models of human performance, especially manual control of vehicles. Lectures and student critique of research literature. Design of systems involving man as a decision maker or as a passenger, conducted in small groups throughout the term. *L. R. Young, Sheridan*

16.45J *Space Communications* (A)
(Same subject as 6.569J)
Prereq.: ——
Year: G (1) 3–0–9
Study involving the important interaction between the orbital and dynamical characteristics of spacecraft, the transmission of electromagnetic signals over long distances, and the concepts of modern communication theory. Stress on interplay between these diverse topics in practical space communication systems. Discussions of spacecraft dynamics, stabilization, attitude control, propagation effects and pertinent modulation and coding methods. *(Some background in space dynamics or in communications assumed. Permission of instructor required.)*
Harrington

16.46 *Astronautical Guidance I* (A)
Prereq.: 18.05
Year: G (1) 3–0–6
Fundamentals of celestial mechanics; orbital initial value, boundary value and orbital transfer problems; two-body and n-body approximate and precision orbit determination. One-way and round-trip trajectory problems to the moon and planets. Fundamentals of space vehicle navigation with particular emphasis on self-contained techniques; statistical error analysis. Techniques of linear perturbation theory, vector and matrix algebra freely applied. *Battin*

16.47 *Astronautical Guidance II* (A)
Prereq.: 16.37 or 16.46
Year: G (2) 3–0–6
Techniques of powered-flight guidance and navigation; velocity-to-be-gained methods; terminal control. Linearized and explicit techniques for fixed- and variable-time-of-arrival guidance. Optimum navigation and guidance policies. Guidance of continuous and low-thrust vehicles; guidance for satellite rendezvous; atmospheric entry guidance. Effect of component inaccuracies on performance of missions. *Battin*

16.48 *Elements of Digital Guidance Computers* (A)
Prereq.: 6.251 or 6.47
Year: G (1) 3–0–6
Introduction to the composition and use of digital computers for guidance systems. Reviews methods of logical analysis and deals with digital computer organizations, logical circuit elements, input-output methods, fixed and erasable memory systems, and basic supervisory program structures. Discussion of power, speed, and size relationships. *Alonso*

16.49 *Special Problems in Weapons Systems* (A)
Prereq.: 16.41
Year: G (1 or 2) *Arr.*
Problems of interest to qualified students in consultation with the instructor. *Wrigley*

16.50 *Vertical Take-Off Aircraft* (A)
Prereq.: 16.11
Year: G (1) 3–0–6
Analysis of inherent performance stability and control characteristics of vertical take-off and landing aircraft, including helicopters and ducted fan, tilt wing, jet vectored-lift, and jet vertical-lift aircraft. *Ham*

(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.

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, aerodynamics, and automatic control to problems encountered in the design of helicopters. Problems of control and stability during transition to horizontal flight, design of stabilization systems, vibration and flutter of rigid or articulated rotors, and analysis of rotor airloads in forward flight. *Ham*

16.53 ***Rocket Propulsion***
Prereq.: 16.001; 16.02 or 16.03
Year: U (2) 3–0–6
Velocity requirements for orbital and interplanetary trajectories. Solid propellant grain design, nozzle performance. Thermochemistry of liquid propellant rockets, flow of chemically reacting gases, calculation of specific impulse. Turbopumps. Heat transfer in nozzles. The rocket engine treated as a complete system. *Lewellen*

16.531 ***Mechanics of Two-Phase Flow*** **(A)**
Prereq: 16.02 or 16.03
Year: G (2) 3–0–9
Introduction to the mechanics of fluid-particle flow with emphasis on an understanding of the roles played by each phase in various physical phenomena. Transport properties of particle-fluid suspension. Continuum description of particle-fluid flow. Dynamics of particles in nozzle flows, normal shocks and mixing and combustion zones. Incompressible fluid-particle flow. Sedimentation and fluidization. Electrodynamics of suspensions. *Tam*

16.54 ***Aircraft Engines***
Prereq.: 16.001; 16.02 or 16.03
Year: U (1) 3–0–6
Performance characteristics of ramjets and gas turbine engines, related to the characteristics of components — inlets, compressors, combustors, turbines, nozzles. Engine-airframe performance characteristics. Emphasis on factors which will determine future trends in engine development. *Kerrebrock*

16.55 ***Ionized Gases*** **(A)**
Prereq.: 8.211
Year: G (1) 3–0–9
Equilibrium description of ionized gases, composition, energy states, statistical mechanics and ionization equilibrium. Kinetic energy, motion of charged particles in magnetic fields, distribution function, collisions, Boltzmann equation, characteristic lengths and times, cross sections, transport properties. Gas-surface interaction, thermionic emission, surface ionization, sheaths, probe theory. Waves and radiation in plasmas, diagnostics. *Solbes*

16.561 ***Nuclear Rockets*** **(A)**
Prereq.: 16.53, 18.05
Year: G (1) 3–0–9
Study of the problems and potentialities of utilizing nuclear energy for space propulsion systems. Typical subjects: suitable missions, fission reactor physics, compromises involved in designing a solid-core nuclear rocket, radiation shielding, and the fluid dynamic and heat transfer problems which must be solved to make various advanced nuclear systems technically feasible. *Lewellen*

16.562 ***Space Power*** **(A)**
Prereq: 16.55
Year: G (2) 3–0–9
Fundamentals of space power systems; thermodynamic and systems considerations for maximum power to mass ratio. High-temperature energy converters; plasma diodes, liquid metal magnetohydrodynamic generators, magnetoplasmadynamic generators. Emphasis is on power for electric propulsion and other applications requiring high power. *Kerrebrock, Solbes*

16.57 ***Electric Propulsion*** **(A)**
Prereq: 16.55
Year: G (2) 3–0–9
Study of the most promising electrostatic, electromagnetic and electrothermal thruster concepts. Identification and evaluation of major loss mechanisms and determination of resultant performance and efficiency using both analytical models and experimental data. Application of these electric propulsion concepts to space flight missions to determine trajectory characteristics and mission performance capability compared with other propulsion system types. *Kerrebrock*

16.581J ***Advanced Topics in Plasma Kinetic Theory*** **(A)**
(Same subject as 22.69J)
Prereq.: 22.68J
Year: G (2) 3–0–9
Varying content including topics of current interest. Typical subjects: theories of non-linear phenomena in plasma, particularly in the regime described by the Vlasov equation; general normal mode analysis, Van Kampen modes, radiation, limitations of the linear theory, resonance and trapping, continuum modes; multiple length-and-time-scale formulations; non-linear stationary wave solutions, shock waves; unstable plasmas, phase space and statistical considerations, entropy; computer experiments; perturbation methods, quasi-linear theory, mode coupling; N-momentum space description, master equation, general H-theorem, equilibrium. *McCune, Dupree*

16.59 ***Introduction to Plasma Kinetic Theory*** **(A)**
Prereq.: 6.58 or 8.311T
Year: G (1) 3–0–9
Collective behavior in collisionless fully ionized plasmas; theory of the Vlasov equation. Waves in plasma without magnetic field, particle-wave resonance; Landau damping. Resonant and non-resonant electrostatic instabilities. Dynamics of a magnetized plasma; particle drifts, currents, constants of the motion; adiabatic invariants. Moment equations and the "double-adiabatic" approximation. Drift-kinetic equation; low-frequency instabilities. Examples of microinstability in anisotropic plasmas. Micro-turbulence and "collisions"; approximations to the plasma kinetic equation. *McCune*

16.60 ***Advanced Special Projects*** **(A)**
Prereq.: ——
Year: G (1, 2) *Arr.*
Study or laboratory project work of graduate level by qualified students. Topics selected in consultation with the instructor. *Staff*

16.605 ***Special Projects***
Prereq.: ——
Year: U (1, 2) *Arr.*
Study or laboratory project work of undergraduate level by qualified students. Topics selected in consultation with the instructor. *Staff*

16.62 ***Experimental Projects***
Prereq.: 8.02
Year: U (1, 2) 2–6–4
Designed to help the student to gain practical insight through "project" experiments. Emphasis on preparation of the project goals, planning of details for the necessary apparatus, conducting of the experiment and relation of the experimental results to the initial goals. Provides not only an opportunity for the student to assemble and apply the knowledge he has gained, but also provides him with a link between theory and practice. *Staff*

16.65 ***Experimental Techniques in Aerodynamics*** **(A)**
Prereq.: 16.02 or 16.03
Year: G (1) 3–0–9
Study of experimental techniques in aerodynamics from two points of view. First, discussion of the problems of specific instrumentation. Then, consideration of the relative motion between the model and airstream in terms of both moving and stationary models. Attention given to practical considerations that may be encountered in actual test programs, as well as consideration of the problems of using testing facilities now being developed. *Covert*

16.70 ***Aircraft and Spacecraft Design***
Prereq.: ——
Year: U (1) 2–4–0
Lectures on preliminary design procedure with applications to an airplane and a satellite. Practice in drawing and in the detail design of components. *Bentley*

16.71 ***Flight Vehicle Engineering***
Prereq.: ——
Year: U (1) 2–3–7
Design of an atmospheric flight vehicle to satisfy stated performance, stability, and control requirements. Emphasis on individual initiative and application of fundamental principles and the compromises inherent in the engineering design process. (*Restricted to seniors in Course* XVI.) *Ham*

16.73 ***Space Systems Engineering***
Prereq.: 16.01, 16.201
Year: U (1) 4–0–8
Review of fundamental principles used in engineering development of space vehicles and application to specific mission analysis. Trajectory kinematics, booster requirements, entry dynamics, propulsion systems, structural design, thermal protection, weight estimation, environmental control and component layout. *Mar*

16.74 ***Advanced Space Systems Engineering*** **(A)**
Prereq.: 16.201 or 16.53 or 16.73
Year: G (2) 2–3–7
Application of the engineering sciences to a typically complex aerospace systems design project. Mission analysis, system analysis and design, system integration. Specialized technical fields supported by outside guest lecturers. Students will participate as teams, each responsible for one of several subsystems, providing actual experience in project organization and the methods by which individuals and teams work together to define and achieve a mutual goal. *Sandorff*

16.751J ***Flight Transportation*** **(A)**
(Same subject as 1.221J, 15.483J)
Prereq.: 16.30
Year: G (1) 3–0–6
Integrated discussion covering basic concepts and operational characteristics of flight transportation systems. Methods of predicting vehicle performance, anticipating future design trends, and determining direct operating costs; airport design and functional layout; guidance and control techniques, both in terminal area and en route; communication and radar system performance.
R. H. Miller, Bone, S. Myers

16.752J ***Flight Transportation Seminar***
(Same subject as 1.222J, 15.484J)
Prereq.: ——
Year: G (1) 1–0–2
Economics of airline operation, problems of financing, and of domestic and international route allocation. Subject developed around seminars presented by speakers from the regulatory agencies, national and international organizations and industry on particular phases of flight transportation. Preparatory lecture preceding each seminar. Opportunity for students to conduct studies in their area of major specialization on a particular topic covered by the subject. *Browne, Bone, S. Myers*

16.77 ***Flight Transportation Operations Analysis*** **(A)**
Prereq.: 1.143 or 15.59 or 16.751J
Year: G (2) 3–0–6
Study of the application of network flow theory to a variety of economic and operational problems in flight transportation systems. Review of graph theory and network flow theory and examples of application in scheduling, passenger traffic flow, aircraft and crew routing, terminal location, timetable optimization, flight planning, etc. Student use of computer to solve large-scale problems and for a term project. *R. W. Simpson*

16.79J ***Legal Aspects of New Technology***
(Same subject as 2.96J)
Prereq.: ——
Year: G (1) 3–0–6
Intellectual property and the law. The nature and progress of invention past and present, the evolution of relevant legal doctrines as an expression of public policy, and present legal doctrines for the treatment of intellectual property as trade secrets, proprietary data, copyrighted materials and patents. Critical analysis of the patent and copyright systems and pending legislation. The impact of selected new technologies — computer technology and xerography. The role of the Federal agencies — with emphasis on the Department of Defense and NASA. The employer-employee relationship, incentives for innovation, employment restraints and employee mobility. Term paper or project required.
Baram

16.81 ***Flight Vehicles***
Prereq.: ——
Year: U (1) 3–0–3
The role of science and engineering in the development of aircraft and spacecraft. Examination of the fundamental problems and solutions of these problems in the light of current technology. *Koppen*

16.82 ***Aerospace Engineering***
Prereq.: ——
Year: U (2) 3–0–3
The work of engineers and scientists in aerospace technology with the Apollo moon project and the supersonic transport as examples. Mission analyses, research and development problems in fluid mechanics and propulsion, materials and structures, automatic control and flight guidance. Interaction among these disciplines in flight vehicle design. *Mar*

16.85 ***Industrial Practice***
Prereq.: ——
Year: U (2) 0–8–0
Seven months of engineering practice carried out by the cooperative students at the plants of organizations participating in the cooperative program. *R. H. Miller*

16.91 ***Continuum Vibrations*** **(A)**
Prereq.: 16.201
Year: G (1) 3–0–6
Dynamics of elastic structures. Free and forced vibrations of bars, beams, strings, plates, multi-mass systems. Differential and integral equations formulation, matrix methods, energy methods. Self-excited vibrations and approximate methods for their solution. *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.

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. (*Not offered 1968–69.*) *Dugundji*

16.94 ***Dynamics of Structures*** **(A)**
Prereq.: 16.91
Year: G (2) 3–0–9
Brief review of Hamilton's Principle, Lagrange's Equations, natural mode shapes and frequencies, and the normal-mode equations of motion. Elastic response of complex structures to gust, blast, and other transient loads. Prediction of large dynamic responses and permanent deformations of shell structures by elastic-plastic and rigid-plastic analysis. Propagation of elastic, elastic-plastic, and extremely intense stress waves in solids. Spall fracture. Hypervelocity impacts. *Witmer*

17.
Political Science

17.01 ***Society and Man***
Prereq.: One first-year Hum. sequence
Year: U (1, 2) 3–0–6
Introduction to the social sciences. Focus on the relation of the individual to his society, considering both the individual's capacity to affect his society and his society's effect on him. Life in the contemporary world examined by such methods as sociological surveys, psychological experiments, mathematical models, and political and anthropological studies. *Feldman*

17.02 ***The Modern World and Social Science***
Prereq.: 17.01
Year: U (2) 3–0–5
Applications of systems analysis to selected current problems of industrial societies, such as peacekeeping, metropolitan growth, big science, formal organizations, and automation. Application of social science data and theories to practical policy decisions in such areas. (*Not offered 1968–69.*) *Pool*

POLITICAL COMMUNICATION AND BEHAVIOR

17.111 ***Public Opinion and Propaganda***
Prereq.: ——
Year: G (2) 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. *Kecskemeti*

17.112 ***Mass Media and Communication Systems***
Prereq.: ——
Year: G (1) *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*

17.121 ***Political Socialization*** **(A)**
Prereq.: ——
Year: G (1) 3–0–6
Study of the processes by which societies and groups regularly teach their members how to behave politically. Examination of approaches to socialization of anthropology, psychoanalysis, and social psychology. Analysis of the main socializing agencies (family, peer group, school, occupation, religion, and voluntary association) to ascertain their distinctive influences. Investigation of national differences in political socialization and ideas of national character. *F. W. Frey*

17.122 ***The Analysis of Power*** **(A)**
Prereq.: 17.721 or 17.722
Year: G (2) 3–0–6
Study of the concepts, measurement techniques, research findings, and hypotheses used in the analysis of interpersonal and intergroup power relations. Emphasis on American political institutions, but with consideration of other institutions and other societies where appropriate evidence is available. *F. W. Frey*

17.131 ***Survey Research Methods*** **(A)**
Prereq.: 17.731 or 17.732
Year: G (2) 3–0–6
Introduction to survey research, with some study of problems in the philosophy of social science and of social scientific experimentation. For students needing to secure or evaluate data about public opinion and attitude formation. *F. W. Frey*

17.14 ***Power, Influence and Policy Decisions***
Prereq.: 17.28
Year: U (1) 3–0–5
Study of the distribution of power in selected types of social units: small groups, organizations, communities, institutions, and nations. Emphasis is placed upon the development of concepts and research techniques necessary for empirical power analysis. Data are drawn from social units in the United States. (*Not offered 1968–69.*) *F. W. Frey*

17.15 ***Political Psychology***
Prereq.: 17.01
Year: U (2) 3–0–5
Selected topics in the relevance of psychology to political behavior including the relationship between personality and political systems and recent psychological findings on the social control of men's behavior. (*Enrollment limited to 15 students. Admission by permission of instructor.*) *Feldman*

17.151 ***Changing Outlooks and Identities in World Affairs*** **(A)**
Prereq.: ——
Year: G (1) 3–0–6
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 in Asia, the world, especially the United States; problems of psychological retooling in the new modes of interaction among Americans, Europeans, Asians, and Africans, particularly as between whites and non-whites. *Isaacs*

17.161 ***Personality, Society, and Politics***
Prereq.: ——
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 1968–69.*)

17.162 ***Identity and Ideology***
Prereq.: 17.01
Year: G (2) 3–0–6
Study of personality theory and political behavior with special emphasis upon the relationships between characteralogical elements and themes and appeals in political ideologies. Case studies of the personal development of historic leaders and the impact of their personalities upon historical processes. *Pye*

17.163 ***Graduate Seminar in Political Psychology* (A)**
Prereq.: ——
Year: G (2) 2–2–5
Examination of the influence of personality, situational and cultural factors on the individual's reaction to perceived authority. Emphasis on experimental socio-psychological data and the design of new experiments. Investigation of differences in cognitive and behavioral characteristics which may be found in different populations. A required original laboratory or field experiment. (*Not offered 1968–69*). *Feldman*

17.191 ***Research Seminar in International Communications* (A)**
Prereq.: 17.111 or 17.112
Year: G (1, 2) *Arr.*

17.192 ***Research Seminar in International Communications* (A)**
Prereq.: 17.111 or 17.112
Year: G (1) *Arr.*
Cooperative examination of key problems in this field. (*Not offered 1968–69.*) *Lerner* (*17.191*); *Staff* (*17.192*)

COMPARATIVE POLITICS

17.21 ***The American Political Process***
Prereq.: ——
Year: U (1, 2) 3–0–5
Examination of the functioning of the American political system in terms of the bases of political power, the evolution and contemporary problems of the modern presidency, and the complementary roles of Congress and the judicial system. Particular emphasis on the interrelationships of power in the system at the national level. *Saloma*

17.211 ***American Federal System* (A)**
Prereq.: 17.21
Year: G (1) 3–0–6
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. (*Not offered 1968–69.*) *Staff*

17.213 ***Graduate Seminar in American Politics* (A)**
Prereq.: 17.21
Year: G (1) *Arr.*
Analysis of the American political system with primary emphasis on the national level. Examination of American political culture, federalism and the American party system. The executive and legislative power structures, the decision making process, and representation and public policy. Special attention to contemporary and comparative research on American politics and government. *Saloma*

17.214 ***Research Seminar in American Political Behavior* (A)**
Prereq.: 17.21
Year: G (2) *Arr.*
Study of the sociology of American politics. Examination of a different research area each year; such as school systems, inter-ethnic relations, or the poverty program. (*Not offered 1968–69.*) *Fein*

17.215J ***Seminar on Metropolitan Development Policy* (A)**
(Same subject as 11.58J)
Prereq.: 17.221
Year: G (2) *Arr.*
Interdisciplinary seminar on policy issues posed by metropolitan development. Evaluation of suburban growth and its impact on the governmental system, public services, and emerging social and economic characteristics of central cities and suburbs. Consideration through research, field work, and case studies of public action for guiding metropolitan development, including intergovernmental relations and national urban policy. *Altshuler, Frieden*

17.216 ***Urban Politics and Problems* (A)**
Prereq.: 17.221
Year: G (2) 3–0–6
Examination of policy making processes of urban America and certain specific urban political issues, with particular emphasis on inter-governmental relations and metropolitan decision making. *Colcord, Altshuler*

17.22 ***Structure of Urban Life***
Prereq.: 17.21
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. *Colcord*

17.221 ***Urban Politics and Planning* (A)**
Prereq.: 17.21 or 17.25
Year: G (1) 3–0–8
Examination of the major political issues and policy-making processes of urban America, with special emphasis on problems of planning and coordination. *Altshuler, Lipsky*

17.222 ***Comparative Asian Politics* (A)**
Prereq.: 17.721
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*

(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.

Descriptions

17.223 ***Asian Political Systems*** **(A)**
Prereq.: ——
Year: G (1) 3–0–5
Introduction to the major political systems of Asia: China, Japan, India. Emphasis on the Western impact on these various systems and on the factors involved in political change and modernization. (*Not offered 1968–69.*) *Weiner*

17.224 ***Chinese Politics*** **(A)**
Prereq.: 17.722 or 17.723
Year: G (2) 3–0–6
Analysis of contemporary Chinese politics, both pre-Communist and Communist. Special focus upon the process of modernization and political development of the Chinese civilization. (*Not offered 1968–69.*) *Pye*

17.225 ***Comparative Asian Politics — South Asia*** **(A)**
Prereq.: 17.01; 17.24 or 17.721
Year: G (2) 3–0–6
Comparative analysis of the political systems of India, Pakistan, and Ceylon. Traditional political and social organization, the impact of the West, the development of nationalist movements, contemporary patterns of political and social change. Special attention to the relationship between political and economic development and social organization. (*Open to undergraduate majors in the Humanities and Social Sciences.*) *Weiner*

17.23 ***Seminar in Contemporary Urban Sociology***
Prereq.: 17.21 or 17.24
Year: U (2) 3–0–5
Examination of the sociology of urban life; ethnicity, class, poverty; special attention to race. *Lipsky*

17.232 ***Seminar: Politics and Government of Sub-Sahara Africa*** **(A)**
Prereq.: 17.61
Year: G (2) 3–0–6
Reading and discussion of special problems relating to nation-building, political development, political integration, and broader political union in Africa. Study covering the interrelation of political structures to political processes with respect to the above mentioned problem areas. (*Not offered 1968–69.*) *W. R. Johnson*

17.24 ***Comparative Political Systems***
Prereq.: 17.01
Year: U (2) 3–0–5
Comparative study of the organization and use of political and economic power in contemporary foreign political systems: Britain, West Germany, and France. Emphasis on the development of attitudes and political customs and the components of democratic political systems. *G. E. Hansen*

17.241 ***The Politics of Western Europe***
Prereq.: ——
Year: G (2) 3–0–6
Introduction on the present position of Western Europe in the world, covering particularly economics, security, and the technological gap, followed by discussion of the domestic and foreign policies of the major West European states. Instruction by the professors in charge, with guest lectures by other members of the faculty.
Lerner, W. E. Griffith

17.242 ***Politics in the Transitional Middle East*** **(A)**
Prereq.: 17.24
Year: G (1) 3–0–6
Comparative analysis of structures of power in Turkey, Iran, and Egypt. Problems in locating and explaining changes in configurations of power in the Middle East, especially related to efforts at social and economic development. The relationship between attitudinal patterns and social structure. Various political science approaches to the common analysis of both Western and non-Western politics; the development of political theories of cross-cultural generality. *F. W. Frey*

17.25 ***State and Local Politics***
Prereq.: 17.21
Year: U (1) 3–0–5
Analysis of state and local political systems and their interaction in dealing with contemporary metropolitan problems. Emphasis on sociocultural bases of political systems and sources of political influence. *Colcord*

17.26 ***The Politics of National Economic Control***
Prereq.: ——
Year: U (2) 3–0–5
Analysis of the policy-making processes and major political issues associated with governmental efforts to guide the American economy. Brief examinations of nationalization and planning in Western Europe for comparative purposes. *Altshuler*

17.261 ***Communism and Revolution***
Prereq.: ——
Year: G (1) 3–0–6
The ideology and practice of Communist political and social revolution, with primary emphasis on Soviet experience through the Stalin era. Marx, Lenin, and the Bolshevik seizure of power; role of the Communist party; the trauma of forced change in a backward society; the totalitarian model. The export of revolution with comparative analysis of the experience of selected additional Communist parties and states: the victory of nationalism over revolutionary internationalism. *Blackmer*

17.262 ***Soviet Foreign Policy and the Communist World*** **(A)**
Prereq.: 17.261
Year: G (1) 3–0–6
Primarily an examination of recent Sino-Soviet relations, but including also Soviet dealings with East Europe and, to a lesser extent, with the non-ruling parties. Brief review of Soviet state and party relations with China and East Europe during the Stalin period, followed by a more detailed analysis of the course of events since 1953.
W. E. Griffith

17.263 ***Soviet Political System*** **(A)**
Prereq.: 17.261
Year: G (2) 3–0–6
Research seminar on the operation of the Soviet system, with special emphasis on change and continuity since Stalin's death. The transition from a developing to a modern industrial society and its consequences for the Communist party and other Soviet institutions. Case studies of such contemporary problems as literature, industrial management, agriculture, elite politics. Interest group theory and other comparative approaches to the evolution of Soviet society. *Blackmer*

17.264 ***Research Seminar on Sino-Soviet Relations and International Communism*** **(A)**
Prereq.: 17.262
Year: G (2) *Arr.*
Techniques of research in Communist affairs, with special reference to Sino-Soviet relations after the death of Stalin: the decipherment of esoteric communications with respect to changes of policy and personnel and to inter-party relations. Readings, research problems, and a seminar paper. (*Not offered 1968–69.*) *W. E. Griffith*

17.265 *Communist Propaganda* (A)
Prereq.: 17.261
Year: G (2) 3–0–6
After brief consideration of Nazi and other totalitarian propaganda doctrine and practice, a detailed study of doctrine, strategy, and tactics of Soviet and Chinese propaganda operations. Some attention to other Communist propaganda operations. (*Not offered 1968–69.*)
W. E. Griffith

17.266 *Domestic and Foreign Politics of East Europe*
Prereq.: ——
Year: G (1) 3–0–6
Analysis of the domestic problems and foreign relations of the Communist states of East Europe since World War II. *W. E. Griffith*

17.267 *Radical and Revolutionary Ideologies*
Prereq.: 17.261
Year: G (2) 3–0–6
Primarily a historical survey of the development of Marxist-Leninist ideology: its background, modifications, and current pluralistic tendencies. Some attention to other radical ideologies, notably anarchism and fascism. *W. E. Griffith*

17.27 *Bureaucracy*
Prereq.: 17.21
Year: U (2) 3–0–5
Study of the structure of public organizations and the politics of bureaucracy in the United States. Examination of major theories of bureaucracy and public administration with reference to specific cases involving policy making, policy execution and the relationship among elected and appointed officials. Special emphasis on the roles of scientists and professionals in the administrative process. *Sapolsky*

17.271 *Theories and Approaches to the Study of Comparative Politics* (A)
Prereq.: 17.723
Year: G (2) 3–0–6
A comprehensive examination of various approaches which underlie our study of comparative politics, with literature drawn primarily from Western Europe. The utility of alternate conceptualizations and theoretical formulations found in the general literature on comparative politics. (*Alternate years. Not offered 1968–69.*)
Pye

17.28 *Political Parties*
Prereq.: 17.21 or 17.24
Year: U (2) 3–0–5
Analysis of political parties and their role in decision making in the political system. Primary attention to the American party system, national party organization, Presidential nominating conventions, electoral strategies, and party leadership in Congress. Comparison with parliamentary, totalitarian, and developing political systems. *Saloma*

17.282 *Comparative Politics of Latin America* (A)
Prereq.: ——
Year: G (2) *Arr.*
Exploration of issues in making cross-national and intranational comparisons of political systems emphasizing the specific problems raised by the need to use and integrate diverse data bases (historical, economic, organizational, attitudinal). Emphasis on Brazil, Chile, and Venezuela. *Staff*

DEFENSE POLICY

17.31 *Evolution of Strategic Nuclear Systems*
Prereq.: 17.52
Year: U (1) 3–0–5
Introduction to the history of the development of strategic nuclear forces and strategy. Consideration of major alternative postures and their implications for deterrence and arms control. Projections of the future role and limitations of strategic nuclear forces.
Kaufmann

17.311 *Development of General War Systems and Strategies* (A)
Prereq.: 17.511 or 17.53
Year: G (1) 3–0–6
Analysis of major U.S. policy decisions concerning general war systems and strategies in the postwar period. Emphasis on the technological, strategic, political, budgetary, and environmental factors that have affected these decisions. Examination of the role of innovation and analysis in the evolution of general war systems and strategies. *Kaufmann*

17.312 *Development of Limited War Systems and Strategies* (A)
Prereq.: 17.311
Year: G (2) 3–0–6
Analysis of major U.S. policy decisions concerning limited war systems and strategies in the postwar period. Emphasis on the determination of force structures and on changing views about the utility of nuclear weapons, the problem of escalation, and the relationship between limited war and general war forces and strategies.
Kaufmann

17.32 *Evolution of Forces for Limited War*
Prereq.: 17.31
Year: U (2) 3–0–5
Introduction to the history of concepts about limited war developed since World War II. Comparison of nuclear and non-nuclear forces for the deterrence and conduct of limited war. Analysis of the problem of escalation and its control. Consideration of current U.S. requirements for limited war forces. *Kaufmann*

17.322 *Research Problems in Defense* (A)
Prereq.: 17.331
Year: G (2) 3–0–6
Examination of a major problem-area in the realm of U.S. defense policy. Main focus on history of the evolution of the problem, consideration of U.S. objectives, and examination of alternative solutions to the problem.
Kaufmann

17.331 *Principles of Systematic Policy Analysis* (A)
Prereq.: 17.731
Year: G (1) 3–0–6
Systems analysis of policy choices. Cost-benefit analysis and related techniques. Political and bureaucratic constraints on analytic procedures. The role of judgment in problem formulation and in the selection of cost and benefit criteria. *Staff*

17.332 *Seminar in Systematic Policy Analysis* (A)
Prereq.: 17.331
Year: G (2) 3–0–6
Collaborative research on simplified policy choices illustrative of the problems facing the Federal and local governments today. Cases selected from such areas as defense, poverty programs, urban affairs, and education. Cost-benefit calculations. *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.

17.342 ***Negotiation and Force in International Relations*** **(A)**
Prereq.: 17.31 or 17.311; 17.52
Year: G (2) 3–0–6
Analysis of tacit bargaining and negotiation: the role of diplomatic customs, commitments, threats and military force. The use of force for bargaining: coercion, deterrence, war aims and war termination. Interaction between negotiation and the formulation of foreign policy. *Staff*

17.352 ***Research and Development and National Security*** **(A)**
Prereq.: ——
Year: G (2) 3–0–6
Management of government sponsored research and development in the U.S., its interrelations with national policy and organization; the problem of ascertaining those relations among the technological community, the Congress, the Executive Branch, and industry which will best facilitate the generation of new ideas and the further development of technology; case studies and problems in other countries. *A. G. Hill*

SCIENCE AND PUBLIC POLICY

17.412T ***Scientific Development and Government Policy*** **(A)**
Prereq.: 17.21
Year: G (1) 3–0–6
History of development of science and technology in the American government, especially post-war. Current science policy issues, with emphasis on allocation of resources, government/private sector relations, decision-making machinery in government and role of scientists and engineers. First section of a two-part sequence (see 17.413). Each may be taken separately by special permission. *Skolnikoff*

17.413 ***Technology and Policy*** **(A)**
Prereq.: 17.412T
Year: G (2) 3–0–6
Important subject areas in which science and technology take form as substantive issues of public policy. Intensive examination of several illustrative areas such as atomic energy, outer space, the marine environment, arms and arms control, and health. Basically, an exploration in depth of concrete policy examples of the general principles and problems discussed in 17.412T.
Bloomfield, Skolnikoff

17.42 ***Government, Politics and Technology***
Prereq.: ——
Year: U (1) 3–0–5
An examination of the impact of science on political structures and processes; the major public policy issues that 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 will explore actual cases of political controversy involving technological change. *Sapolsky*

17.422 ***Public Management of Science***
Prereq.: ——
Year: G (1) 3–0–6
A study of the Federal government's support and use of science and technology, emphasizing major organizational issues. An analysis of the problems of organizational competition, policy planning and coordination, Executive-Congressional relations, the science advisor's role in administration, the management of research, and institutional autonomy. *Sapolsky*

17.431 ***Science and American Foreign Policy*** **(A)**
Prereq.: 17.412T
Year: G (2) 3–0–6
Examination of the scientific component in U.S. foreign-policy making, including the scientific and technological bases of key issues in foreign policy, opportunities scientific programs offer for the more effective realization of U.S. objectives; pattern of international scientific collaboration; role of scientists in foreign policy process. *Skolnikoff*

17.442 ***American Science and Its Development: Current Issues and Problems*** **(A)**
Prereq.: 17.412T
Year: G (2) *Arr.*
Seminar designed to bring together selected faculty members and graduate students to consider a single major public issue in science-government relations each year and to subject it to sustained analysis. Seminar report representing the collective contributions of the participants issued at the end of the term. *Skolnikoff, Bolt*

17.443J ***Public Policy and Use of the Seas***
(Same subject as 13.92J)
Prereq.: ——
Year: G (1) 3–0–6
Policies of the United States and other nations toward possession and use of the seas. Interfaces between technology and public policy. Laws and agreements relating to jurisdiction in the maritime frontier, use of Continental Shelf, navigation, exploitation of ocean resources, deep submergence, and pollution. Role of the U.N. and other agencies. New goals for national policy.
Padelford

INTERNATIONAL RELATIONS AND FOREIGN POLICY

17.51 ***International Relations***
Prereq.: 14.01 or 17.01 or 21.05
Year: U (1, 2) 3–0–5
Basic factors and trends in contemporary world politics. Models of the international system; dynamics of politics; imperialism; nationalism; east-west struggle; revolution in developing nations; impact of technology. Decision making processes and basic interests of the great powers. Comparative instruments of foreign policy; the United Nations; regional arrangements. Case study of the war in Vietnam. *Padelford, Giddens*

17.511 ***Theory and Practice of International Relations*** **(A)**
Prereq.: 17.51 or 17.52
Year: G (1) 3–0–6
The conceptual framework of international relations; analysis of classical and contemporary theories; examination of efforts to structure a disciplinary and analytical approach to the subject; their relevance to actualities of international politics. Emphasis on acquisition of familiarity with the literature and methodology of the field. *Alker*

17.513 ***Function of Law in the World Community*** **(A)**
Prereq.: 17.511 or 17.521 or 17.53
Year: G (1) 3–0–6
Role of international law in the development of political community at the regional and global levels. Nature and subjects of international law. Rights and duties of states. The law and the individual. Territorial questions with special reference to boundaries, territorial waters, the high seas, air and outer space. Peaceful settlement of disputes; peace-keeping; place of the U.N. Use of force and the international rule of law. *(Not offered 1968–69.)* *Padelford, Giddens*

17.514 ***The U.N. System and Problems of Political Development*** **(A)**
Prereq.: 17.511 or 17.53
Year: G (2) 3–0–6
The structure, process, and politics of international organizations, particularly within the U.N. 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. *Padelford*

17.516 ***Research Seminar in International Relations*** **(A)**
Prereq.: 17.53
Year: G (2) 3–0–6
Individual directed research and reading on problems of international politics, law and organization. *Padelford*

17.52 ***Principles and Problems of American Foreign Policy***
Prereq.: 17.51
Year: U (1, 2) 3–0–5
The American experience — underlying assumptions and major objectives of American foreign policy. Emphasis on relationship between social and institutional structures within which foreign policy is made, and substantive foreign policy issues: NATO, relations with the Soviet bloc and China, the United Nations, and the underdeveloped world. *G. E. Hansen, Giddens*

17.521 ***U.S. Foreign Policy — Process and Problems*** **(A)**
Prereq.: 17.51 or 17.52
Year: G (1) 3–0–6
A critical analysis of the contemporary U.S. foreign policy scene in the context of broad national strategy. The process of policy-making including organization, formulation, and execution. Analysis in depth of selected issues. (*Not offered 1968–69.*) *Bloomfield*

17.522 ***U.S. Foreign Policy — Plans and Strategies*** **(A)**
Prereq.: 17.521
Year: G (2) 3–0–6
The planning of foreign policy in the context of broad national strategy. The questions of foreign policy goals and interests and of developing short- and long-term political doctrines and strategies. Illustrative problems, with emphasis on simulation (political-military gaming) and other special techniques for contingency planning. (*Not offered 1968–69.*) *Bloomfield*

17.523 ***Research: International Relations and Foreign Policy*** **(A)**
Prereq.: 17.521 or 17.522
Year: G (1) 3–0–6
Problem approach to selected areas and issues, based on particular student interests. *Bloomfield*

17.53 ***Seminar in International Politics***
Prereq.: 17.52
Year: U (1) 3–0–5
Selected problems to complete a three-term sequence in international relations. Problems varying from year to year, but most recently emphasizing the international relations of Asia, and with special regard for American policy. *G. E. Hansen*

17.54 ***Arms Control, Disarmament, and Foreign Policy***
Prereq.: 17.51
Year: U (1) 3–0–5
Analysis of the problems of disarmament and arms control and the issues involved for American foreign and defense policy, against a background of diplomatic history, technological change, and politico-military strategy. *Bloomfield*

POLITICAL AND ECONOMIC DEVELOPMENT

17.61 ***Political and Economic Development of Tropical Africa***
Prereq.: 17.01 or any political science subject
Year: U (1) 3–0–5
Evaluation of the major ideas relating to, and study of the major facets and problems of economic and political development in tropical Africa. *W. R. Johnson*

17.611 ***Personality, Social Stability, and Social Change*** **(A)**
Prereq.: 17.15
Year: G (1) 3–0–6
Relation of personality to social structure in the explanation of social stability and change. Traditional societies as social-cultural-personality systems. Analysis of their stability or instability. Emphasis on evidence from village studies. Limited analysis of societal change, especially "modernization." *Hagen*

17.612 ***Seminar in Social Stability and Change*** **(A)**
Prereq.: 17.611
Year: G (2) 3–0–6
Amplified discussion of selected literature relating personality to social structure in the analysis of social change. Study of two societies, probably Burma and Japan, to illustrate the theoretical analysis. Term paper concerning an empirical problem. *Hagen*

17.62J ***Impact of the West on Africa***
(Same subject as 21.549J)
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Examination of the ideological, political, and economic bases of imperialism and colonial rule; the ending of the slave trade, the exploration of Africa, the new evangelism, the partition of Africa, the methods of colonial rule, and the response of Africans thereto during the nineteenth and twentieth centuries. *Rotberg*

17.621 ***The Development of Political Organizations*** **(A)**
Prereq.: 17.722
Year: G (1) 3–0–6
Examination of the factors involved in the origins, development, and maintenance of various types of political organizations. Particular attention given to the creation of political parties and the maintenance of local party organizations in underdeveloped areas. (*Not offered 1968–69.*) *Weiner*

17.623 ***Social Organization and Political Change in Developing Areas*** **(A)**
Prereq.: 17.721 or 17.722
Year: G (1) 3–0–6
Analysis of principles of social organization, social stratification, and social mobility as they affect various aspects of political development such as political participation, political leadership, political organization, legitimacy, and political integration. *Weiner*

17.63 ***Seminar: Mechanisms and Forms of Protest***
Prereq.: ——
Year: U (1) *Arr.*
Comparative analysis of the varieties of self-assertion: resistance movements, rebellions, millennialism, and struggles for independence. (*For advanced undergraduates and graduate students.*) *Rotberg*

(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.

17.631 *Theories of Political Development* (A)
Prereq.: 17.52
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*

17.64 *Political Science Seminar*
Prereq.: ——
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 1968–69.*) *Staff*

17.652 *Field Research in Political Development* (A)
Prereq.: 17.131
Year: G (2) *Arr.*
Seminar in field research methods for political research in developing areas. Intended only for students who will begin field research the following academic year. *Weiner*

17.71 *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*

17.711 *Reading Seminar in Social Science* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*

17.712 *Reading Seminar in Social Science* (A)
Prereq.: ——
Year: G (1, 2) *Arr.*
Reading and discussion of special topics in the fields of social science. Open to advanced graduate students by arrangement with individual staff members. ——

17.721 *Concept Formation and Research Technique in the Social Sciences*
Prereq.: ——
Year: G (1) 3–0–6
Requirements for testable concepts and theory building with behavioral data. Logical foundations of evidence and inference, quantity and quality, parts and wholes, cause and effect. Research technique in sample surveys, controlled experiment, clinical diagnosis, statistical tests. Emphasis on reanalysis of extant and created data. (*Not offered 1968–69.*) *Lerner*

17.722 *Theory of Political Processes*
Prereq.: ——
Year: G (1) *Arr.*
Analysis of various theories of the political process. Particular attention paid to theories concerning the formation of a consensus about the legitimacy of a government and the consequences of conflict and conformity within nations. A different author read and discussed each week. *Pool*

17.723 *Introduction to the Social Sciences* (A)
Prereq.: ——
Year: G (1) 3–0–6
Extensive reading and analysis of the classic works in modern social and political science theory. Systematic review of the various traditions of contemporary social science. Primarily designed for the first-year graduate student without a broad background in social science. *Pye*

17.724 *Topics in Political Theory*
Prereq.: ——
Year: G (1) *Arr.*
International interaction: The balance of power. Shifting coalitions, feedback, and multipolarity. Empire-building and the decomposition of empire. The initiation and termination of conflict. *Political Power and Society:* The dimensions of power: coercion, influence, authority. Authority and influence. The ruling class. The Marxian hypothesis. Political stability and instability. Revolution. *Typology of Political Systems:* Classical typologies (Plato, Aristotle, Polybius). Imperial and feudal rule. The problem of "oriental despotism." Bureaucratic absolutism. Consensual, pluralistic and totalitarian democracy. *Kecskemeti*

17.73 *Mathematical Politics*
Prereq.: 17.01
Year: U (2) 3–0–5
Mathematical modeling of political processes including alternate descriptions and evaluations of their inputs, mechanisms and outcomes. Election or referendum campaigns, national decision making, and international conflict. A year of previous social science work or reading required. *Alker*

17.731 *Introduction to Mathematical Models in the Social Sciences*
Prereq.: ——
Year: G (1) 3–0–6
Introduction to the use of mathematical models and formal mathematical analysis in sociology and political science. Study of the necessary mathematics as a part of the subject. For students with little mathematical background. *Lehrer*

17.732 *Statistics for the Social Sciences*
Prereq.: ——
Year: G (2) 3–0–6
Basic concepts and techniques useful in social science. Introduction to descriptive statistics, sampling, point and interval estimation, testing of hypotheses, correlation and contingency, regression, and non-parametric methods. No mathematical or statistical prerequisites. *Lehrer*

17.733 *Introduction to Computers for Political Scientists*
Prereq.: ——
Year: G (1) 2–2–2
Introduction to computers with examples designed especially for behavioral science application. Some emphasis on non-numerical computation. *Staff*

17.734 *Data Structure for Symbol Manipulation*
Prereq.: 17.731
Year: G (2) 2–0–6
Basic structure of the MAD compiler. Communication of parameters. FAP and MAD external functions. Imbedding subsystems in MAD. List processing. The available space issue. The responsibility issue and list erasure. Sequencing over complex list structures. Modifying complex list structures. Text manipulation within SLIP. Input-output of list structures. Extensions of list processing ideas to more general data structures. *Weizenbaum*

17.735 *Seminar in Model Building in Political Science*
Prereq: ——
Year: G (1) 2–0–6
Specific political or social organization studied from the point of view of designing a computer model representing it. Model built and run by the seminar. *Weizenbaum*

17.736 ***Multivariate Political Analysis*** **(A)**
Prereq.: 17.731, 17.732
Year: G (1) 3–0–6
Focus on multivariate data analysis procedures. Regression analysis, analyses of variance and covariance, tree-building, recursive and simultaneous dynamic equation systems, cluster analysis, factor analysis, and multi-dimensional scaling. Attempt by students to make causal inferences from some set of political data. *Alker*

17.75 ***Prediction in Social Science and Public Policy***
Prereq.: 14.02 or 17.02
Year: U (1) 3–0–5
Methodological problems in sociology and political science relevant for policy decisions. Description, causation, and prediction. Population trends and their consequences. Indicators of social change and of social problems. The relationship between prediction and decision making. *Staff*

18.
Mathematics

18.00 ***Elementary Number Theory***
Prereq.: ——
Year: U (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, rational approximations of real numbers. Emphasis on mathematical rigor and methods of proof. *G. B. Thomas*

18.01 ***Calculus***
Prereq.: ——
Year: U (1, 2) 4–0–8
Study of functions of one variable. Brief review of the elementary functions. Basic properties of functions, such as boundedness, periodicity, growth rate. Limits and continuity. Differentiation, with applications. Solution of the simplest differential equations. Integrability, the definite integral, fundamental theorem of calculus. Applications to geometrical problems. Integration techniques, improper integrals. The mean value theorem and its generalization to Taylor's theorem, with applications to calculation of the elementary functions. *Toomre*

18.02 ***Calculus***
Prereq.: 18.01
Year: U (1, 2) 4–0–8
Study of functions of several variables. Vector algebra in three-space. Scalar functions of two and three variables; partial differentiation, gradient, approximation techniques. Double and triple integration, with applications. Vector functions of one variable, analysis of space motion, Kepler's laws. Vector functions of two and three variables, vector fields. Line integrals, Green's theorem in the plane, conservative fields. Surface integrals in space; the divergence (Gauss's) theorem; Stokes' theorem. *Toomre*

18.034 ***Differential Equations***
Prereq.: 18.02
Year: U (1, 2) 3–0–9
Elementary linear algebra, linear differential equations with constant coefficients, geometry of solutions, existence and numerical computation of solutions, non-linear equations, phase plane, linear systems with variable coefficients, series solutions. *Hunter*

18.05 ***Advanced Calculus for Engineers*** **(A, *except Courses II, VI, VIII, XII, XIII, XVI, XVIII, XXII*)**
Prereq.: 18.034
Year: G (1); U (1, 2, S) 3–0–9
Functions of a complex variable; calculus of residues; conformal mapping. Ordinary differential equations; integration by power series; Bessel and Legendre functions. Expansion in series of orthogonal functions, including Fourier series. Hildebrand, *Advanced Calculus for Applications*. *Hildebrand*

18.06 ***Advanced Calculus for Engineers*** **(A, *except Courses II, XVI, XVIII, XXII*)**
Prereq.: 18.05
Year: G (1, 2, S) 3–0–9
Vector analysis: orthogonal curvilinear coordinates. Calculus of variations. Solution of classical equations of mathematical physics, including applications of conformal mapping and the Laplace transformation. Partial differential equations; characteristics. Hildebrand, *Advanced Calculus for Applications*. *Hildebrand*

18.07 ***Review of Mathematics***
Prereq.: ——
Year: G (S) 8–0–12
Review of calculus and differential equations. (*Restricted to selected officers of the U.S. Army, Air Force, Navy and Coast Guard.*) *Staff*

18.08 ***Sophomore Seminar in Applied Mathematics***
Prereq.: 18.034
Year: U (2) 2–0–4
A broad survey by the staff of modern developments in applied mathematics with active student participation. (*Enrollment limited. Not offered 1968–69*). *Greenspan*

18.081 ***Principles of Applied Mathematics***
Prereq.: 18.034
Year U (1) 3–0–9

18.082 ***Principles of Applied Mathematics***
Prereq.: 18.034
Year: U (2) 3–0–9
A general introduction to the fundamental principles of applied mathematics: propagation, equilibrium, stability, optimization, cybernetics, and random processes. Development of the related mathematics and applications. *Greenspan* (18.081), *Papert* (18.082)

18.091 ***Advanced Calculus*** **(A, *except Courses II, VI, VIII, XII, XIII, XVI, XVIII, XXII*)**
Prereq.: 18.034
Year: G (1) 3–0–9

18.092 ***Advanced Calculus*** **(A, *except Courses II, XVI, XVIII, XXII*)**
Prereq.: 18.091
Year: G (2) 3–0–9
Functions of a complex variable, ordinary differential equations, special functions, Sturm-Liouville problems. Advanced vector analysis, potential theory, Fourier series and integral transforms, boundary value problems. (Essentially the same material as that covered in 18.05 and 18.06, but at an advanced level to satisfy the prerequisites for the Methods of Applied Mathematics sequence beginning with 18.653. Students should have A's and B's in previous mathematics subjects, and should not be mathematics majors.) *Barcilon*

(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.

18.10 ***Applications of Probability and Random Variables***
Prereq.: 18.02
Year: U (2) 3–0–9
Theory of probability and random variables on an elementary level with emphasis upon mathematical models having wide applicability. Discrete and continuous random variables, joint distributions, derived distributions, expected value, difference equations, generating functions, some elementary aspects of queuing theory and Markov processes, decision making, and some probabilistic methods in the control of operations. Stress on applications from a wide choice of fields.
Wadsworth

18.13 ***Numerical Analysis* (A)**
Prereq.: 18.05 or 18.651
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*

18.15 ***Methods of Applied Mathematics for Engineers* (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; constraints, direct methods. Formulation and treatment of integral equations; Green's function; analytical and numerical methods of solution. Hildebrand, *Methods of Applied Mathematics.*
Hildebrand

18.16J ***Heuristic Programming and Artificial Intelligence* (A)**
(Same subject as 6.544J)
Prereq.: ——
Year: G (2) 3–0–9
The problem of making machines behave intelligently. Application of machines to problems of learning, induction, pattern-recognition, game-playing, theorem-proving, neural nets, self-organizing systems, and other areas where problems have been solved by heuristic programming. Problems in administration and allocation of effort within programs. Models of cognitive processes. Machine aids for human problem solving. (*Ability to program a computer required.*) *Papert, Minsky*

18.162 ***Applied Computability***
Prereq.: 18.034
Year: U (2) 3–0–9
Theory of algorithms, programs and abstract machines. Applications to problems in pattern recognition, languages and decidability. (*Enrollment limited to 25 students.*) (*Not offered 1968–69.*) *Papert, Blum*

18.163 ***Theory of Computers* (A)**
Prereq.: 6.253 or 18.25
Year: G (1) 3–0–9
Recursive function theory with special emphasis on the results which reveal the fundamental properties of computing systems. Recursion theorem and the related self-scanning machines. Machine-independent theorems on speed and efficiency of computation, length of algorithms, real-time computation. (*Not offered 1968–69.*)
Blum

18.165J ***Computability, Formal Systems, and Logic***
(Same subject as 6.262J)
Prereq.: 6.261 or 18.25
Year: U (2) 4–0–8
Study of the basic concepts underlying mathematical theories of computation, with applications to automata theory, programming, and theorem proving. General purpose algorithm schemes and their properties. Recursive derivation, Turing machines and idealized computers. Universal algorithms and the design of universal machines. Computable and non-computable functions. Semantic and syntactic properties of formal systems. The undecidability of various syntactic problems, such as Post's correspondence problem and the tag problem. Logical systems, models, and valuation. Gödel's completeness and incompleteness theorems and their implications. *Blum, Hennie*

18.17 ***Combinatorial Theory* (A)**
Prereq.: 18.034
Year: G (1) 3–0–9
Survey of combinatorial problems of current research interest. Topics include enumerative analysis, theory of partitions, graph theory, knot theory, network flow, theory of matroids, matrices of zeros and ones, combinatorial designs, representations of the symmetric group, combinatorial methods in statistical mechanics, combinatorial geometry, Ramsey's theorem, matching theory, asymptotic enumeration. Varying content from year to year, so that students may take the subject in successive years. *Rota*

18.18 ***Probability***
Prereq.: 18.034
Year: U (2) 3–0–9
Random variables and expectations. Laws of large numbers, fluctuation theory, recurrent events, Markov chains, birth-and-death processes, introduction to the general theory of stochastic processes. *Rota*

18.182 ***Introduction to Stochastic Processes* (A)**
Prereq.: 18.18
Year: G (2) 3–0–9
Independence. Zero-one laws of Borel-Cantelli and Kolmogorov. Chebyshev's and Kolmogorov's inequalities. Distribution functions and transforms. Classical limit theorems (deMoivre-Laplace, Poisson, strong law of large numbers). Random walks, Markov chains, Poisson processes, Brownian motion and diffusion. Connection with differential and integral equations. (*Not offered 1968–69.*) *Ray*

18.20 ***Linear Algebra***
Prereq.: 18.034
Year: U (1, 2) 3–0–9
Vector spaces, euclidean spaces, linear transformations, linear equations, matrices, determinants, quadratic forms, canonical forms of matrices. If 18.20 is taken after credit has been received in 18.25, then credit is *not* permitted in both 18.20 and 18.26. Hoffman and Kunze, *Linear Algebra.* *Curtis*

18.21 ***Analysis* (A, *except XVIII*)**
Prereq.: 18.034
Year: U (1, 2); G (1, 2) 3–0–9
Real numbers and euclidean n-space; open, closed and compact subsets of n-space. Continuous and differentiable functions. Uniform convergence. Fourier series, power series and analytic functions. Note: 18.20 will be helpful as additional preparation. *K. M. Hoffman*

18.22 *Analysis* (A, *except XVIII*)
Prereq.: 18.20 or *18.26*; 18.21
Year: G (2) 3–0–9
Lebesgue integration in euclidean space. Differentiable maps, Jacobians and the inverse function theorem. Change of variables. Differential forms and Stokes theorem. *K. M. Hoffman*

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.: 18.21
Year: U (2) 3–0–9
Emphasis on classical theory of space curves and surfaces. Frenet formulas, fundamental forms, theorems of Meusnier and Euler, lines of curvature, asymptotic and conjugate lines, geodesics, equations of Gauss, Cadazzi and Weingarten, special surfaces, mapping problems and existence theorems. Additional topics to be chosen from geometry in the large, classical tensor theory and Riemannian geometry. *Wan*

18.241 *Introduction to Topology*
Prereq.: 18.20 or *18.25;* 18.21
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. *Whitehead*

18.242 *Riemannian Geometry*
Prereq.: 18.22, 18.241
Year: U (2) 3–0–9
Elementary manifold theory, differential forms and the De Rham theorem, first and second fundamental forms for surfaces, curvature and the Gauss-Bonnet theorem, embedded surfaces. *Guillemin*

18.25 *Modern Algebra*
Prereq.: 18.034
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. *Mattuck*

18.27 *Introduction to Functions of a Complex Variable* (A, *except XVIII*)
Prereq.: 18.034
Year: G (1) 3–0–9

18.28 *Introduction to Functions of a Complex Variable* (A)
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. Singular integral equations.
Wan (18.27); Cheng (18.28)

18.31 *Theory of Functions* (A)
Prereq.: 18.21
Year: G (1) 3–0–9
Cauchy's integral theorem, residue theorem and applications. Series and product representations of analytic functions. Entire and meromorphic functions. Simple Riemann surfaces. Conformal mapping. Additional topics may be included. *Pukanszky*

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, Riemann surfaces, uniformization, quasi-conformal mapping, Fourier and Laplace transforms, special functions. *Pukanszky*

18.33 *Functions of Complex Variables* (A)
Prereq.: 18.31
Year: G (2) 3–0–9

18.34 *Functions of Complex Variables* (A)
Prereq.: 18.33
Year: G (2) 3–0–9
Various aspects of the theory of analytic functions. Content varying from year to year, so that students may take the subject in successive years. (*18.34 not offered 1968–69.*) *Maskit*

18.35 *Functions of Real Variables* (A)
Prereq.: 18.22
Year: G (1) 3–0–9

18.36 *Functions of Real Variables* (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. Elements of Banach spaces, Hahn-Banach and closed graph theorems. Topics on linear transformations of L^p spaces. *K. M. Hoffman*

18.363 *Abstract Analysis* (A)
Prereq.: 18.25, 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 1968–69.*) *Segal*

18.365 *Mathematical Analysis of Fundamental Physics* (A)
Prereq.: 18.36
Year: G (2) 3–0–9
Introductory account of the following subjects and, particularly, their interrelations: probability in function space; the theory of partial differential equations of evolution; and infinite-dimensional representations of continuous groups. Special emphasis will be placed on features applicable to contemporary theoretical physics. (*Not offered 1968–69.*) *Segal*

(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.

18.366 ***Mathematical Analysis of Fundamental Physics*** **(A)**
Prereq.: 18.365
Year: G (2) 3–0–9
Rigorous development from the foundations laid in 18.365 of the following: scattering theory; constructive quantum field theory; representations of the Lorentz group and its extensions; invariant quantum statistical systems. (*Not offered 1968–69.*) *Segal*

18.368 ***Hilbert Space*** **(A)**
Prereq.: 18.36
Year: G (2) 3–0–9
General theory of bounded and unbounded operators in Hilbert space. Applications to quantum field theory. (*Not offered 1968–69.*) *Glimm*

18.37 ***Functional Analysis*** **(A)**
Prereq.: 18.27 or 18.31; 18.35
Year: G (1) 3–0–9
General theory of linear topological spaces. Locally convex spaces, duality; category theorems, ordered spaces. Distributions and generalized functions; tensor products and kernels. Applications. *Dudley*

18.38 ***Functional Analysis*** **(A)**
Prereq.: 18.37
Year: G (2) 3–0–9
Banach algebras, spectral theory in Hilbert space. C*-algebras; rings of operators. Applications to harmonic analysis on groups and manifolds. Content varying from term to term so that graduate students may take the subject in successive terms. *Dudley*

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 1968–69.*) *Levinson*

18.43 ***Partial Differential Equations*** **(A)**
Prereq.: 18.22
Year: G (1) 3–0–9

18.44 ***Partial Differential Equations*** **(A)**
Prereq.: 18.43
Year: G (2) 3–0–9
The Cauchy-Kowalewski theorem, existence and regularity of solutions of the Dirichlet problem for linear elliptic equations, existence and regularity of solutions of the Cauchy problem for hyperbolic linear equations, fundamental solutions for linear equations with constant coefficients. (*18.44 not offered 1968–69.*)
Ambrose (18.43); Strang (18.44)

18.49 ***Harmonic Analysis and Potential Theory***
Prereq.: 18.21
Year: U (2) 3–0–9
Elementary theory of Fourier series and Fourier integrals; Riesz-Fischer and Plancherel theorems; Fourier-Stieltjes transforms; potentials of mass distributions; harmonic functions; the Dirichlet problem. *Helgason*

18.53 ***Theory of Probability*** **(A)**
Prereq.: 18.22 or 18.49
Year: G (1) 3–0–9
Probability measures, Borel fields, conditional probabilities, sums of independent random variables, limit theorems, zero-one laws, martingales. *Kleitman*

18.54 ***Theory of Probability*** **(A)**
Prereq.: 18.53
Year: G (2) 3–0–9
Topics selected by the instructor, for example, Markov processes, stationary processes, ergodic theory, diffusion processes and stochastic differential equations. (*Not offered 1968–69.*) *Ray*

18.57 ***Theory of Approximation Methods*** **(A)**
Prereq.: 18.20 or 18.26
Year: G (1) 3–0–9
Analysis of constructive methods for the solution of algebraic and differential equations and eigenvalue problems. Applications of functional analysis. Constructive theory of functions. Over-relaxation and other iterative schemes for large systems of difference equations. *Strang*

18.58 ***Partial Difference Equations*** **(A)**
Prereq.: 18.20 or 18.26
Year: G (2) 3–0–9
Parallel treatment of initial-value problems for partial differential equations and their finite difference analogs; equivalence of convergence and stability for linear systems; von Neumann's method of stability analysis in L_2 by Fourier transform; Lax theory of non-linear conservation laws. *Strang*

18.59 ***Statistical Mechanics*** **(A)**
Prereq.: 8.421
Year: G (1) 3–0–9
Selected topics, primarily in equilibrium statistical mechanics, with emphasis on rigorous mathematical results on specific problems. Discussion in detail of exactly soluble models such as the two-dimensional ferromagnet and ferroelectric models. Mathematical theories of phase transitions. Cluster expansion methods. *Lieb*

18.60 ***Introduction to Fluid Mechanics***
Prereq.: 18.05 or *18.651*
Year: U (1) 3–0–9
Dynamics of frictionless fluids; mathematical description; some basic concepts and theorems. Equilibrium configurations. Potential flows; vortex motion; conformal transformations. Gravity waves; normal modes, group velocity; Kelvin-Helmholtz instability. Sound waves and atmospheric oscillations. Shallow-water theory; characteristics; bores and shocks. Elements of the theory of viscous fluids; some exact solutions; boundary layer theory. *Toomre*

18.611 ***Rotating Fluids*** **(A)**
Prereq.: 18.60, 18.653
Year: G (1) 3–0–9
General theory of rotating fluid motions; transient flows; effects of viscosity, stratification, and compressibility; non-linear interactions; wave motions; applications.
Barcilon

18.612 ***Introduction to Geophysical Fluid Dynamics*** **(A)**
Prereq.: 18.60, 18.653
Year: G (1) 3–0–9
Fundamentals of the dynamics of homogeneous and stratified rotating fluids. Transient and steady flows. Models of geophysical phenomena. (*Not offered 1968–68.*)

18.62 ***Hydrodynamic Stability and Turbulence*** **(A)**
Prereq.: 8.08T, 18.60, 18.651
Year: G (2) 3–0–9
General theory of turbulent motion. Equations of hydrodynamics. Statistical theory of turbulence. Structure of the energy-containing eddies. Dynamics of the equilibrium range. Closure problem. Eddy viscosity. Analytical theories. Renormalization theory. Lagrangian-

history direct-interaction theory. Hydromagnetic turbulence. Turbulent thermal convection and turbulent shear flow. Turbulent diffusion. Turbulence in a collisionless plasma. Collisionless shocks. Anomalous diffusion. (*Not offered 1968–69.*) ——

18.63 *Mathematical Learning Theory* (A)
Prereq.: 18.05
Year: G (1) 3–0–9
Introduction of a learning theory with psychological and physiological implications in terms of some non-linear difference — differential networks. Interpretation also as a non-stationary statistical and/or deterministic prediction theory. Global limit and oscillation theorems. Influence of geometry on dynamics (i.e., "geometry of learning"). Time evolution of entropy. Study of reversible and irreversible behavior. Application to data: e.g., verbal learning (bowing, chaining, backward learning, reminiscence, presentation rate, list length, chunking, context effects), lateral inhibition, thresholds, spiking frequencies, transmitter production and release, ionic fluxes, reaction time, masking, pattern learning, some anatomical examples. Comparison with classical developments: e.g., Gestalt, Hull, Pavlov. *Grossberg*

18.634 *Topics in Applied Mathematics* (A)
Prereq.: 6.253 or 6.261 or 18.25
Year: G (1) 3–0–9
Varying content from term to term so that students may take the subject in successive terms. Theory of automata. Algebraic approach to structure of finite state machines. Relation of special classes of automata to computational problems. *Papert*

18.636 *Stellar Dynamics and Galactic Structure* (A)
Prereq.: 8.06; 18.06 or 18.652
Year: G (2) 3–0–9
Types and compositions of galaxies; mass distributions and kinematics. General dynamics of stellar systems: Liouville and Boltzmann equations, isolating integrals; encounters, relaxation times; epicyclic stellar orbits. Dynamics of interstellar material: observations; hydromagnetic equations; gravitational stability of a gas. Theory of star clusters and elliptical galaxies. Gravitational stability of a disk-shaped galaxy; spiral structure. (*Not offered 1968–69.*) ——

18.64 *Kinetic Theory of Gases* (A)
Prereq.: 8.08T
Year: G (1) 3–0–9
Introduction to the general theory of non-equilibrium statistical mechanics. Formulation of kinetic equations in the dilute gas, weak coupling, and plasma regimes. Perturbation theories of Prigogine and Balescu, Bogoliubov, and Frieman and Sandri. Non-perturbative theory of dense gases and plasmas. (*Not offered 1968–69.*) *Orszag*

18.641 *Mathematical Theory of Modern Physics* (A)
Prereq.: 18.28
Year: G (1) 3–0–9
Mathematical theory of modern physics. Analytic properties of scattering amplitudes in the energy, the momentum transfer, and the angular momentum variables; single dispersion relation; double dispersion relation; Regge pole and representation theory; symmetry principles and particle physics. (*Not offered 1968–69.*) *Cheng*

18.65 *Integral Equations* (A, *except XVIII*)
Prereq.: 18.034
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. (*Not offered 1968–69.*) *Crout*

18.651 *Introduction to Applied Mathematics*
Prereq.: 18.20 or 18.26; *18.21*
Year: U (1) 3–0–9
Interdependence of mathematics and scientific problems, examples; deterministic and random processes; particle mechanics and differential equations, Brownian motion and random walk. Fourier series; tensors; partial differential equations of mathematical physics and continuum mechanics. Linear programming. Calculus of variations. *C. C. Lin*

18.652 *Introduction to Applied Mathematics*
Prereq.: 18.651
Year: U (2) 3–0–9
Potential theory, boundary value problems for the partial differential equations of mathematical physics, method of separation of variables. Sturm-Liouville problems, Fourier integrals. Applications of the calculus of variations. Information theory. *Hunter*

18.653 *Methods of Applied Mathematics I* (A)
Prereq.: 18.092 or 18.27
Year: G (1) 3–0–9

18.654 *Methods of Applied Mathematics II* (A)
Prereq.: 18.28, 18.653
Year: G (2) 3–0–9
General mathematical theory of partial differential equations and methods of solution with applications to physical problems. Topics include single equations of the first order; characteristic surfaces and the classification of equations of higher order and systems of equations; properties of hyperbolic, parabolic, and elliptic equations, boundary conditions and well-posed problems, the application of integral transform and other methods to their solution. Asymptotic approximations. Integral equations; Fredholm and Hilbert-Schmidt theory, singular integral equations, application of integral transforms including Wiener-Hopf method, dual integral equations, Riemann problem. Calculus of variations.
Bleistein (18.653); Orszag (18.654)

18.655 *Methods of Applied Mathematics III* (A)
Prereq.: 18.652 or 18.653
Year: G (1) 3–0–9
Asymptotic methods of non-linear mechanics. Singular perturbation theory, matched asymptotic expansions, P.L.K. method, multiple scaling procedures, boundary layer techniques, applications to non-linear problems. *Benney*

18.656 *Wave Motion* (A)
Prereq.: 18.655
Year: G (2) 3–0–9
Review of linear waves. Non-linear interactions of discrete waves and wave trains. Asymptotic methods for dispersive and non-dispersive waves, characteristics, breaking, permanent waves, Whitham's theory. Non-linear stability. Non-linear random waves, propagation in random media, closure, special topics. *Benney*

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18.66 ***Introduction to Elasticity***
Prereq.: 18.05 or 18.651
Year: U (2) 3–0–9
Analysis of stress and strain. Stress-strain relations. General stress and displacement function solutions. Variational principles and uniqueness theorems. Applications of functions of complex variables and transforms. Wave propagation in elastic media. St. Venant theory of stretching, bending, torsion and flexure of prismatic bodies. Linear theory of plates. *Wan*

18.67 ***Theoretical and Applied Elasticity*** **(A)**
Prereq.: 2.071 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. Parametric expansion methods. Theories of beams, plates and shells. (*Not offered 1968–69.*) *Reissner*

18.681 ***Theoretical and Applied Elasticity*** **(A)**
Prereq.: 18.68
Year: G (1) 3–0–9
Special topics in the linear and non-linear theory of beams, plates and shells. (*Not offered 1968–69.*) *Reissner*

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. (*Not offered 1968–69.*) ——

18.721 ***Algebraic Geometry*** **(A)**
Prereq.: 18.731
Year: G (1) 3–0–9

18.722 ***Algebraic Geometry*** **(A)**
Prereq.: 18.721
Year: G (2) 3–0–9
Introduction to contemporary algebraic geometry. Content varying from year to year with topics selected from the following: elementary properties of algebraic varieties over arbitrary ground fields, linear systems, Riemann-Roch theorem for curves and surfaces; algebraic groups and abelian varieties, complex toruses and theta functions; equivalence theories, rational equivalence ring, Chern classes, generalized Riemann-Roch theorem; Grothendieck schemes, sheaves, cohomology of varieties and schemes in various senses, holomorphic functions, Hilbert schemes, Picard scheme, fundamental group. (*Not offered 1968–69.*) *Artin*

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. Additional topics varying yearly. *Artin*

18.735 ***Homological Algebra*** **(A)**
Prereq.: 18.732
Year: G (1) 3–0–9

18.736 ***Homological Algebra*** **(A)**
Prereq.: 18.735
Year: G (2) 3–0–9
Abelian categories, derived functors, spectral sequences, the functors Tor and Ext, cohomology of sheaves, homological properties of noetherian rings. Grothendieck topologies, the derived category of an abelian category, local duality theory, semi-simplicial methods and a unified cohomology theory for algebraic structures. (*Not offered 1968–69.*) *Quillen*

18.74 ***Topics in Algebra*** **(A)**
Prereq.: 18.731
Year: G (1) 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 groups, non-commutative rings and algebras, Lie algebras, local rings. *R. Steinberg*

18.75 ***Nonassociative Algebras*** **(A)**
Prereq.: 18.731
Year: G (1) 3–0–9
Non-associative algebras. Alternative and Jordan algebras. Relationships with Lie algebras, particularly the exceptional simple Lie algebras. Power-associative algebras, or other additional topics as time permits. (*Not offered 1968–69.*) *Schafer*

18.763 ***Algebraic Number Theory*** **(A)**
Prereq.: 18.731
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. 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. *Ankeny*

18.77 ***Theory of Numbers***
Prereq.: 18.20 or *18.25; 18.21*
Year: U (1) 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. (*Not offered 1968–69.*) *Ankeny*

18.78 ***Topics in the Theory of Numbers*** **(A)**
Prereq.: 18.20 or 18.25; 18.21
Year: G (2) 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. (*18.79 not offered 1968–69.*)
H. M. Stark

18.80 ***Recursion Theory*** **(A)**
Prereq.: 18.20 or 18.25 or 18.886 or *18.89*
Year: G (1) 3–0–9
Recursive functions, recursively enumerable sets and their complements, fixed-point theorems, Post's problem, priority arguments. Degrees of unsolvability, the jump operator, inclusion relations among recursively enumerable sets. *Rogers*

18.802 ***Higher Recursion Theory*** **(A)**
Prereq.: 18.80
Year: G (2) 3–0–9
Arithmetical, hyperarithmetical, and analytical hierarchies. Recursive ordinals, hyperdegrees, hyperjump. Generalized recursive function theory. *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. *G. W. Whitehead*

18.821 ***Graduate Topology Seminar*** **(A)**
Prereq.: 18.82
Year: G (1) 3–0–9
Study and discussion of important original papers in the various parts of algebraic and differential topology. *Kan*

18.83 ***Advanced Topology*** **(A)**
Prereq.: 18.82
Year: G (2) 3–0–9
Content varying from term to term so that graduate students taking the subject in successive terms may have an introduction to several important phases of topology such as homotopy theory, cohomology theory, fibre spaces, K-theory, combinatorial topology, and/or differential topology. *Curtis*

18.831 ***Differential Topology*** **(A)**
Prereq.: 18.82
Year: G (2) 3–0–9
Introduction to differential topology. Differentiable manifolds, immersion and imbedding theorems, vector bundles, characteristic classes. Other possible topics include surgery, cobordism, piecewise-linear and differentiable structures, Morse theory, Whitehead torsion. (*Not offered 1968–69.*) *Munkres*

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. *Friedberg*

18.85 ***Lie Groups and Lie Algebras*** **(A)**
Prereq.: 18.22, 18.26
Year: G (1) 3–0–9
Lie groups and Lie algebras over complete fields; structure and representation theory. (*Not offered 1968–69.*) *Kostant*

18.86 ***Lie Groups and Lie Algebras*** **(A)**
Prereq.: 18.85
Year: G (1) 3–0–9
Semisimple Lie groups and symmetric spaces. Topics in function theory on symmetric spaces, such as Fourier analysis and Radon transform, invariant differential operators and potential theory. Emphasis on connections with classical analysis and representation theory. *Helgason*

18.861 ***Representations of Lie Groups*** **(A)**
Prereq.: 18.85
Year: G (2) 3–0–9
Cartan-Weyl finite-dimensional representation theory of semisimple Lie groups. Theory of roots and weights. Weyl character formula. Decomposition of tensor products and reduction to a subgroup. *Kostant*

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, differential forms, De Rham and Dolbeault theorems, cohomology of sheaves, differential operators on manifolds, resolution of the solution sheaf of a differential equation: formal and analytic theory. *Guillemin*

18.881 ***Elliptic Operators*** **(A)**
Prereq.: 18.22, 18.242, *18.81*
Year: G (1) 3–0–9

18.882 ***Elliptic Operators*** **(A)**
Prereq.: 18.881
Year: G (2) 3–0–9
Local theory of elliptic differential and singular integral operators, extension to vector bundles over manifolds, coercive boundary value problems, K(x), index theorem and applications, elliptic complexes, fixed point theorem, Spencer resolution. (*Not offered 1968–69.*) *I. M. Singer*

18.886 ***Introduction to Mathematical Logic***
Prereq.: 18.20 or 18.25
Year: U (2) 3–0–9
Formal systems of mathematical logic. Propositional calculus. Quantification theory. Models, validity, and semantic implication. Completeness theorem, Skolem-Löwenheim theory, proof procedures. Axiomatic theories, e.g. set theory. Brief treatment of undecidability and incompleteness of axiomatic theories. *Sacks*

18.89 ***Mathematical Logic*** **(A)**
Prereq.: 18.20 or 18.25
Year: G (1) 3–0–9
Classical systems of logic; their use in the formalization of mathematical argument. Algebraic structure in logical systems. Completeness theorem, Skolem-Lowenheim constructions, compactness arguments. Brief study of recursive functions and Gödel incompleteness theorem. (*Not offered 1968–69.*) ——

18.892 ***Theory of Models*** **(A)**
Prereq.: 18.886 or *18.89*
Year: G (2) 3–0–9
Elementary equivalence, elementary extensions, saturated models, automorphisms of models, categoricity in power. Element types, model-completeness, elimination of quantifiers. Applications to theories of fields. Nonstandard analysis. *Sacks*

18.893 ***Set Theory*** **(A)**
Prereq.: 18.886 or *18.89*
Year: G (1) 3–0–9
Axiomatic set theory. Undecidability of continuum hypothesis and axiom of choice. Consequences of large cardinal hypotheses. *Sacks*

18.894 ***Proof Theory*** **(A)**
Prereq.: 18.89
Year: G (2) 3–0–9
Consistency and incompleteness. Positive results of Gentzen and his school. Negative results of Gödel. Constructive interpretation of classical results. (*Not offered 1968–69.*) ——

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. *Levinson*

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19.
Meteorology

19.003 ***Elementary Meteorology I***
Prereq.: ——
Year: U (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 edition. *Staff*

19.14 ***Long-Range Weather Forecasting*** **(A)**
Prereq.: 19.45
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.: 19.45
Year: G (1) 3–0–6
Lecture part of 19.14. *Willett*

19.22 ***Air and Sea Instruments*** **(A)**
Prereq.: 12.811 or 19.83; 19.43
Year: G (2) 3–2–6
Lectures and laboratory exercises on the design and response characteristics of typical instruments and instrument systems used for measurements in the atmosphere, in the oceans, and in the sea-air interfacial region. *Keily*

19.24 ***Fluid Dynamics Laboratory*** **(A)**
Prereq.: 1.612 or 2.201 or 16.041 or 18.60 or 19.62
Year: G (2) 2–4–4
Experiments on processes and phenomena in geophysical fluid mechanics. Design of experiments, similarity, experimental methods, data processing. Laboratory work involving quantitative observation of hydrodynamic instability, transport processes and turbulence. *Mollö-Christensen*

19.34 ***Statistical Methods in Meteorology***
Prereq.: 18.034
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, non-linear statistical forecasting, significance of empirical relations, and hypothesis testing. *Lorenz*

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 non-linear methods of statistical weather forecasting. *(Alternate years.)* *Lorenz*

19.43 ***Synoptic Meteorology I***
Prereq.: 8.02, 18.02
Year: U (1) 2–2–4
The state of the atmosphere including the three-dimensional variation of significant meteorological variables. The heat budget of the atmosphere on a global and local scale. The physical processes associated with the formation of fog, smog, cumulus clouds, thunderstorms, and tornadoes. Introduction to the dynamics of cyclones and hurricanes. World and local climate. Petterssen, *Weather Analysis and Forecasting*, 2nd edition, Vol. II. *J. M. Austin*

19.45 ***Synoptic Meteorology II*** **(A)**
Prereq.: 19.43
Year: G (2) 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 circulations. Simple dynamical prediction models. Petterssen, *Weather Analysis and Forecasting*, 2nd edition, Vol. 1. *Sanders*

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. Derivation and study of some simple atmospheric models for numerical forecasting. *Phillips*

19.53 ***Synoptic Laboratory*** **(A)**
Prereq.: 19.43
Year: G (2) 0–4–8
Study of atmospheric phenomena in the troposphere and stratosphere by analysis of meteorological data. Consideration of scales ranging from the global general circulation to severe thunderstorm complexes. Data sources include the global network of surface and upper-level balloon sounding stations on land and at sea, aircraft data, rocket soundings in the stratosphere, weather radar, and meteorological satellites. Weather prediction as a probabilistic science. Contemporary operational forecasting as a man-machine system. *Sanders*

19.601 ***Introduction to Dynamical Meteorology***
Prereq.: 18.034
Year: U (1) 3–0–6
Thermodynamics of moist air, development of hydrodynamical principles for small-scale atmospheric motion. Convective instability and analysis of simple models of turbulent convection. *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*

19.65 *Turbulence and Random Phenomena in Fluid Mechanics* (A)
Prereq.: 1.612 or 2.201 or 16.041 or 18.60
Year: G (2) 3–0–6
Development of descriptions of random fields starting from statistics of ensembles of random functions. Response of systems and fields to random inputs, with examples of filters, dispersive and non-dispersive wave phenomena. Turbulence, descriptors and closure problems. Analogies with kinetic theory. Sources of turbulence, hydrodynamic stability, homogeneous turbulence, equations, spectra, equilibrium and decay. Shear flow turbulence, turbulent boundary layers. The atmospheric boundary layer. Turbulence in a stratified medium. Generation of surface waves by wind. Methods of observation, measurement and analysis.
Mollö-Christensen

19.67 *Planetary Fluid Dynamics* (A)
Prereq.: 18.60
Year: G (1) 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.: 8.03T, *18.02*
Year: U (2) 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 *Atmospheric Precipitation Processes* (A)
Prereq.: 8.03T, 19.43
Year: G (1) 2–2–4
Origin and growth of hydrometeors; atmospheric motions of mesoscale and the morphology of convective and stratiform storms. Elementary principles of radar with applications to the observation of precipitation processes on the mesoscale. Laboratory exercises on the evaluation of radar data and on the operation of radar systems.
P. M. Austin

19.72 *Physical Meteorology* (A)
Prereq.: 8.04, 18.02
Year: G (2) 3–0–6
Absorption and scattering of solar radiation in the atmosphere and the spatial and temporal distribution of solar radiation at the surface of the earth. Theory of radiative transfer in the atmosphere, radiation charts, and the radiative heat balance of the atmosphere and earth. Nucleation of water and ice in the atmosphere. Growth of drops and ice particles by condensation and accretion. Mechanisms for the release of precipitation and their interaction with the dynamics of the atmosphere. *Houghton*

19.74 *Physics of the Upper Atmosphere* (A)
Prereq.: 8.04, 18.034
Year: G (2) 3–0–6
Structure, composition and properties of the atmosphere above the tropopause. Wind velocity, temperature, pressure, composition and density data obtained with rockets and satellites up to heights of about 1000 km; discussion of theories which best account for the observations. Interaction between input radiation, both photons and corpuscles, and atmospheric constituents, together with the effects of conduction, convection, radiation and diffusion. Chapman layer theory applied to the ionosphere and to the layer of ozone. Role of the circulation in the transport of trace substances. Dynamic and energetic interaction between the upper and lower atmosphere. Atmospheric tides, noctilucent clouds, and meteors; various aspects of aurorae pertinent to incident energy stream and interaction. *Newell*

19.80 *Surface and Internal Waves* (A)
Prereq.: 18.60, 19.83
Year: G (1) 3–0–6
Kinematics and dynamics of small-scale oceanic wave motion. Mathematical development of surface gravity and internal waves, their generation and decay, interaction with other wave modes; comparison with observations. *Beardsley*

19.83 *Physical Oceanography I*
Prereq.: 8.02, 18.02
Year: U (1) 3–0–9
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. Von Arx, *Introduction to Physical Oceanography.* *Houghton*

19.84 *Dynamic Oceanography* (A)
Prereq.: 18.05
Year: G (2) 3–0–6
Dynamics of internal gravity waves and rotational waves. Response of the ocean to large-scale mechanical effects from the atmosphere and theories of ocean circulation.
Phillips

19.85 *Physical Oceanography II* (A)
Prereq.: 8.03T, 18.034
Year: G (S) 3–0–6
Physical properties of sea water and ice, research ships and major expeditions, oceanographic instrumentation, dynamics of frictionless ocean currents, frictional forces and wind driven currents, heat budget of the oceans, surface tides, wind waves and internal waves, turbulence and mixing, general circulation of the oceans and adjacent seas. Neumann and Pierson, *Principles of Physical Oceanography.* (*Given at Woods Hole Oceanographic Institution.*) *Siedler* (*Woods Hole Staff*)

19.86 *Oceanic Circulations* (A)
Prereq.: 19.67 or 19.84
Year: G (1 or 2) 3–0–6
Large-scale circulation of the oceans as revealed by the analysis of hydrographic data, direct current measurements and the distribution of properties and tracers. Theories of wind-driven and thermohaline circulations. Emphasis on the relation between observations and recent theories of the main thermocline and the associated thermohaline circulation. *Stommel*

19.87 *Seminar in Physical Oceanography* (A)
Prereq.: 19.67 or 19.86
Year: G (1 or 2) 3–0–6
Readings and discussions of current research topics in physical oceanography. Emphasis on circulations of the ocean with choice of topics from most interesting subjects in current literature. *Stommel*

(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.

19.88 ***Oceanic Variability*** **(A)**
Prereq.: 6.571; 12.811 or 19.83
Year: G (1) 3–0–6
Review of oceanographic processes having time or space dependence; the spectrum of oceanic variability. Methods of observation: response scales of instruments and the design of oceanographic time and space series. *Webster*

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.: 19.43, 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.: 19.43, 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.: 19.43, 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*

19.96 ***Special Subject in Meteorology*** **(A)**
Prereq.: 19.43, 19.601
Year: G (1, 2) *Arr.*
Organized lecture or laboratory subject on some aspect of meteorology not normally covered in the regularly scheduled subjects. *Staff*

19.97 ***Special Subject in Oceanography*** **(A)**
Prereq.: 19.83
Year: G (1, 2) *Arr.*
Organized lecture or laboratory subject on some aspect of oceanography not normally covered in the regularly scheduled subjects. *Staff*

20.
Nutrition and Food Science

20.02 ***Nutrition and Food Science Projects Laboratory***
Prereq.: ——
Year: U (2) 1–8–3
Laboratory work with faculty guidance but emphasizing independent work, designed to introduce the student to the principles and techniques of design and execution of experimental projects in food science and technology, biochemical engineering, food toxicology, and experimental and human nutrition. A four- to five-week introductory project, followed by the design and execution of one or more specific projects of the student's own choice, utilizing recent research techniques.
Wogan, Edozien, V. R. Young, Sinsky

20.11 ***Food Science and Technology***
Prereq.: 5.41, 5.60
Year: U (1) 3–0–5
Basic principles of food preservation including methods of preservation, changes occurring during processing to storage, and the control of changes in food due to enzymes, microorganisms, and chemical reactions. *Staff*

20.12 ***Food Technology Laboratory*** **(A)**
Prereq.: 20.11
Year: G (1) 1–6–3
Laboratory work on a small group basis designed to investigate the chemical, physicochemical and engineering principles of importance to food processing and storage. Areas covered: concentration, dehydration, freezing, thermal processing, irradiation and packaging. Each exercise designed to study the particular effects of the process on the food material and, where applicable, subsequent changes during storage. *Labuza, Tannenbaum*

20.13J ***Food Engineering***
(Same subject as 2.642J)
Prereq.: 2.641
Year: U (2) 4–0–5
Quantitative study of selected unit operations of the food industry with consideration of basic principles governing each operation, as well as of important applications. Emphasis on refrigeration and freezing, fluid flow, heat transfer, evaporation, dehydration and filtration.
Karel, Hesselschwerdt

20.15 ***Advanced Food Engineering*** **(A)**
Prereq.: 20.11, 20.13J
Year: G (1) 1–6–3
Process design problems involving laboratory work, class discussions and plant trips. Detailed consideration of a specific selected food's process, integration engineering and quality factors. Emphasis on analysis of new processes on the basis of information developed through laboratory and pilot plant experiments. (*Alternate years. Not offered 1968–69.*) *Staff*

20.20 ***Flavor Chemistry and Flavor Methodology*** **(A)**
Prereq.: 5.41, 20.11, 20.32
Year: G (1 or 2) 2–0–4
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. (*Alternate years.*) *Wick*

20.30T ***Nutritional Biochemistry and Metabolism***
Prereq.: 7.05
Year: U (2) 4–0–8
Digestion and absorption, nutritional requirements and interrelationships, metabolic functions of individual nutrients, and influence of physiologic state and environment on nutritional needs and metabolic processes.
Munro

20.301 ***Experimental Nutrition*** **(A)**
Prereq.: *20.30T*
Year: G (2) 1–6–2
Discussion and practice of experimental procedures used in nutrition and biochemical research on animals.
S. A. Miller

20.31 ***Advanced Nutritional Biochemistry and Metabolism*** **(A)**
Prereq.: 20.30T
Year: G (1) 3–0–6
Discussion of topics in mammalian metabolism with a bearing on adaptive and other mechanisms that underlie responses to nutritional status. *Munro*

20.32 ***Techniques in Food and Nutrition Research*** **(A)**
Prereq.: 5.14, 5.41, 7.05
Year: G (1) 2–7–4
Lectures and experiments in the principles and use of colorimetric, fluorometric, flame photometric and spectrophotometric analyses; chromatography (ion exchange, gas, paper, thin layer); microbiological and isotope techniques in analysis of nutrients and metabolic intermediates. *Wolf, Wick, Issenberg*

20.36 ***Human Nutrition*** **(A)**
Prereq.: 20.30T
Year: G (1) 3–0–6
Measurement of nutrient requirements and evaluation of nutritional status of man; effects of dietary and conditioned nutrient deficiencies; nutrition in disease; prevention of malnutrition; nutrition education; clinical investigation. (*Permission of instructor required for students who have not taken the prerequisite.*) *Scrimshaw*

20.37 ***Endocrinology*** **(A)**
Prereq.: 20.30T
Year: G (1) 3–0–6
Structure and function of the endocrine glands. Basic nature of abnormalities causing endocrine disease. Biosynthetic mechanisms, hormone transport, molecular basis of hormone action and control systems will be stressed. (*Permission of instructor required for students who have not taken 20.30T.*) *De Groot*

20.38 ***Factors Determining Food Value***
Prereq.: 5.41
Year: U (1 or 2) 3–0–6
Introduction to the chemical and physical basis of food preservation and the impact of processing and storage on the nutritive value of human food supplies. Consideration of Food and Drug Law; stability of vitamins, lipids and proteins; selected food processes which have classically been employed; newer food processes such as irradiation and microwave processing. Discussion on the application of present and future technology to solution of world food problems. *Tannenbaum*

20.391 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05, 20.301
Year: G (1 or 2) 2–0–4

20.392 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05, 20.301
Year: G (1) 2–0–4

20.393 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05, 20.301
Year: G (2) 2–0–4

20.394 ***Advanced Nutrition and Physiological Chemistry*** **(A)**
Prereq.: 7.05, 20.301
Year: G (1 or 2) 2–0–4
Four-term sequence of lectures and discussions of biochemical aspects of nutrition for advanced graduate students, one section being given each term over a two-year period. (*20.393 and 20.394 not offered 1968–69.*) *Staff*

20.40 ***Selected Topics in Nutrition and Food Science*** **(A)**
Prereq.: 20.11, 20.30T
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*

20.41 ***Microbiology Laboratory***
Prereq.: 7.05
Year: U (1 or 2) 2–4–3
Techniques necessary for isolation from natural sources of bacteria, yeasts and molds. Morphological and metabolic characterization of microorganisms. *Silverman*

20.43 ***Industrial Microbiology*** **(A)**
Prereq.: 7.21
Year: G (1) 3–6–4
Selected topics in the uses of yeasts, bacteria, molds and algae for the production of substances of industrial or food value, such as amino acids, antibiotics, organic acids and vitamins, with emphasis on the biochemistry of fermentations. Space travel considerations studied. *Dunn*

20.45 ***Epidemiology of Nutritional and Food-Borne Diseases*** **(A)**
Prereq.: 20.36, 20.46
Year: G (2) 2–2–4
Principles and practice of field epidemiology, medical ecology and modes of transmission: nutritional diseases such as pellagra and kwashiorkor; dental fluorosis and caries; food- and water-borne infectious diseases such as typhoid fever, bacillary dysentery, amebiasis and cholera; food poisoning from bacterial toxins and heavy metals, and intestinal parasitic infections. Prevention of enteric disease and control of epidemics. Synergism between infection and nutrition. Practical field techniques and research methods. *Rubenstein*

20.46 ***Food Microbiology*** **(A)**
Prereq.: 7.05, 20.41
Year: G (2) 3–6–6
Quantitative aspects of bacteriology and their application to food processing. Mathematical considerations of thermal destruction. Methods of detecting bacteria causing food-borne diseases. *Nickerson*

20.47 ***Biochemical Engineering*** **(A)**
Prereq.: 5.62 or 20.13J; 7.05 or 7.21
Year: G (2) 3–3–4
Interactions of chemical engineering, biochemistry and microbiology. Mathematical representation of microbial systems. Kinetics of growth, death and metabolism. Continuous fermentation. Transfer of gases in fermentation systems. Mixing and the measurement of mixing times. Product recovery. Laboratory experiments involving evaluation of mass transfer coefficients, operation of a pilot plant fermentor, computer simulation of fermentation systems, and other topics. *Mateles*

20.48 ***Computer Methods in Applied Biology*** **(A)**
Prereq.: 18.02
Year: G (2) 2–1–6
Application of computer methods to problems drawn from various areas of life sciences. Analog techniques for the solution of problems in enzyme kinetics, unsteady-state heat transfer, and metabolic turnover. Use of MAD to program digital computers for bulk processing and time-sharing applications. Writing and use of pro-

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grams for statistical analysis, sophisticated rate problems, and on-line processing of experimental data. Student problems will be worked by small teams using available analog, digital, and time-sharing facilities. *Mateles, Wang*

20.51 ***Advanced Food Science*** **(A)**
Prereq.: 5.62, 20.11, 20.30T
Year: G (1) 3–0–5
Physicochemical properties of foods and their influence on food stability and quality; mechanism and kinetics of reactions of food components during processing and storage; enzymatic reactions, non-enzymatic browning, lipid oxidation, protein denaturation, and other reactions affecting the acceptability and nutritive value of foods. *Issenberg*

20.52 ***Advanced Food Technology*** **(A)**
Prereq.: 20.13J, 20.51
Year: G (2) 3–0–6
Detailed consideration of selected food processing methods from the point of view of scientific and engineering principles. Colloidal and surface phenomena in processing of foods. Consideration of transport properties of foods in the design of concentration and dehydration processes. Physical and chemical changes occurring during and after food processing. *Karel, Labuza*

20.57 ***Food Applications of Ionizing Radiations*** **(A)**
Prereq.: 8.04, 20.11
Year: G (1) 3–0–6
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. New developments in sources of ionizing energy; consideration of role of legislation from an international point of view as well as the effects of this on the potential uses of ionizing energy. *(Alternate years. Not offered 1968–69.)* *Goldblith*

20.59 ***Food Toxicology*** **(A)**
Prereq.: 20.11, 20.30T
Year: G (2) 3–0–6
Principles and problems in evaluating the wholesomeness and safety of foods, food components, additives, and contaminants. Consideration of selective toxicity, detoxication mechanisms, structure and biological activity; basic concepts and techniques of safety evaluation, and interpretation of biological data. *L. Friedman*

20.591 ***Food Toxicology Laboratory*** **(A)**
Prereq.: 20.301, 20.32, *20.59*, 20.63
Year: G (2) 1–6–2
Studies of acute and subacute toxicity; techniques of biological assay; and parameters of biological response. *L. Friedman*

20.61 ***Seminar in Nutrition and Food Science*** **(A)**
Prereq.: ——
Year: G (1) 2–0–2
20.62 ***Seminar in Nutrition and Food Science*** **(A)**
Prereq.: ——
Year: G (2) 2–0–2
Presentation of recent advances in nutrition, food science and technology. *Staff*

20.63 ***Systemic Physiology*** **(A)**
Prereq.: 7.05, *20.30T*
Year: G (1 or 2) 3–0–6
Basic concepts of physiological processes in intact animal tissues, organs, and organ systems. Principles of functional integration in the maintenance of homeostasis and methods for appraisal of functional status. *(Permission of instructor required for students who have not taken prerequisites.)* *Bransome*

20.64 ***Comparative Histology*** **(A)**
Prereq.: 20.63
Year: G (1) 4–6–6
Study of microscopic and ultramicroscopic structure of cells, tissues and organs of laboratory animals. Relation of structure to function. *(Alternate years.)* *C. E. Hunt*

20.65 ***Nutritional Pathology*** **(A)**
Prereq.: 20.64
Year: G (2) 3–6–6
Comprehensive study of gross and microscopic pathology of nutritional diseases of animals with evaluation and application of selected chemical, histochemical, and cytochemical methods as they apply to localization of enzymes, nucleic acids, amino acids, and other cellular constituents. *(Alternate years.)* *Newberne*

20.651 ***Seminar in Comparative Pathology*** **(A)**
Prereq.: 20.65
Year: G (1) 3–0–3
20.652 ***Seminar in Comparative Pathology*** **(A)**
Prereq.: 20.65
Year: G (2) 3–0–3
Systematic study of disease problems common to various animal species and caused by viral, bacterial, fungal, and toxicological agents. Emphasis on background knowledge of and current areas of research on selected diseases. *Newberne*

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*

20.80 ***Neuroendocrine Control Mechanisms*** **(A)**
Prereq.: 20.37
Year: G (2) 3–0–6
Study of the interactions of the nervous and endocrine systems, with emphasis on the biochemistry of neurotransmitters, and of hormones of neural origin, the anatomy and physiology of the neuroendocrine transducers, the control of endocrine homeostasis and biological rhythms by the central nervous system, the effects of hormones on cerebral functions, and the mechanisms by which certain psychoactive drugs produce endocrine effects. *(Permission of instructor required for students who have not taken 20.37.)* *Wurtman*

20.81 ***Public Health Nutrition*** **(A)**
Prereq.: 20.30T
Year: G (S) 4–0–4
Project visits and seminar discussions of the incorporation of nutrition into public health programs at international and local levels. Bilateral and international technical assistance programs involving nutrition. Application of supplementary feeding and food enrichment techniques. Nutritional factors in relation to growth and development, pregnancy and lactation, and cardiovascular diseases. Interrelationship between infection and nutrition. Dietary requirements for differing environmental and cultural situations. *(Restricted to suitably qualified physicians and dentists.)* *Scrimshaw*

20.82 ***Clinical Nutrition*** **(A)**
Prereq.: 20.30T
Year: G (S) 4–2–4
Four hours of round table discussions and two hours of hospital and clinic visits per week 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, hepatic and cardiovascular diseases, and cancer. (*Restricted to suitably qualified physicians and dentists.*) *Scrimshaw*

20.83 ***Evaluation of Nutritional Status*** **(A)**
Prereq.: 20.30T
Year: G (S) 0–10–4
Field trips twice weekly, in which an opportunity is given to become proficient in clinical appraisal of the nutritional status of different types of populations. 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 suitably qualified physicians and dentists.*) *Scrimshaw*

20.84 ***Metabolic Aspects in Inherited Disease*** **(A)**
Prereq.: 7.05
Year: G (1) 3–0–6
Discussion of the genetic and biochemical principles underlying human inherited disease; principles of human genetics as applied to human disease. Systematic survey of the biochemical lesions of inherited disease. Consideration of therapeutic resources. *Stanbury*

20.85 ***Research Management in the Food and Drug Industries*** **(A)**
Prereq.: ——
Year: G (1 or 2) 2–0–2
Lectures devoted to research management problems peculiar to the food and drug industries and to managerial and 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. Consideration of research as a dominant force in modern society. Consideration of research audits, research management in small and large companies. *Goldblith*

20.871 ***Research Approaches to Oral Biology*** **(A)**
Prereq.: 7.21, 20.30T, 20.64
Year: G (1 or 2) 3–0–6
Discussion of recent advances in oral biology and oral pathology in relation to the basic and life sciences (mathematics, physics, chemistry, biochemistry, histology, physiology, bacteriology, nutrition), especially in relation to experimental animals and human beings. New research approaches to the major problems of oral pathology (dental caries, periodontal disease, bone disease, microbial diseases, tumors) will be discussed in terms of choice of experimental animal, laboratory and clinical procedures, modern instrumentation, and experimental design. *Navia*

20.872 ***Research Approaches to Oral Biology Laboratory*** **(A)**
Prereq.: 20.871
Year: G (1 or 2) 1–6–1
Animal, chemical, and microbiological laboratory exercises designed to demonstrate the newer approaches to research in oral biology and oral pathology using modern instruments. *Navia*

20.88 ***Seminar in Oral Science*** **(A)**
Prereq.: 20.30T
Year: G (1) 2–0–4

20.89 ***Seminar in Oral Science*** **(A)**
Prereq.: 20.30T
Year: G (2) 2–0–4
Presentations of recent advances in oral science by staff, guest lecturers and students. *R. S. Harris*

20.91 ***Experimental Statistics for the Biological Sciences I*** **(A)**
Prereq.: 18.02
Year: G (1) 2–2–4
Designed to give investigators in life sciences a working knowledge of statistical procedures for interpretation of experimental data. Topics including: variation and statistical measures. Probability, frequency distributions and moments; sampling distributions, point and interval estimation, tests of significance. Basic concepts of statistical models and use of samples. Regression and correlation. Analysis of variance and covariance. *Staff*

20.92 ***Experimental Statistics for the Biological Sciences II*** **(A)**
Prereq.: 20.91
Year: G (2) 2–2–4
Variance components. Theory of least squares. Elementary experimental design. Individual degrees of freedom, design of experiments repeated over time and place, factorial arrangements and incomplete block designs. *Staff*

21.
Humanities

21.011 ***The Western Tradition: The Classical Heritage***
Prereq.: ——
Year: U (1) 3–0–6
Reading and discussion of literary and philosophical masterworks central to understanding the ideals and the problems of contemporary Western society. Majority of texts of a literary nature with emphasis on the nature of civilization as the Western tradition has conceived it, its value and cost. Some of the authors to be read: Homer, Aeschylus, Sophocles, Plato, Aristotle, Virgil. *Staff*

21.012 ***The Western Tradition: The European Heritage***
Prereq.: 21.011
Year: U (2) 3–0–6
Continuation of 21.011. Representative works from later periods of the Western tradition. Authors to be included: Dante, Shakespeare, Goethe, Dostoevsky, Freud; additional readings constituting a span of topics ranging chronologically from Christian Antiquity through the Renaissance and Enlightenment. *Staff*

21.013T ***Identity and Autobiography: The Nineteenth Century***
Prereq.: ——
Year: U (1) 3–0–6
Study of the major modes of self-knowledge and self-expression available to modern man. Emphasis on autobiography and literature, with some attention to film, psychology, and philosophy. Reading and discussion of works by Rousseau, Goethe, Wordsworth, Blake, Whitman, Thoreau, Mill, Carlyle, Tennyson, Dostoevsky, Tolstoi, Conrad, and Graves. *Staff*

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21.014T ***Identity and Autobiography: The Twentieth Century***
Prereq.: 21.013T
Year: U (2) 3–0–6
Continuation of 21.013T. The re-evaluation of nineteenth century positions during the period between World War I and World War II, and the attempt since World War II to redefine and interpret the problems of personal identity raised between the wars. Reading and discussion of works by Eliot, Joyce, Pound, Freud, Erikson, Hemingway, Fitzgerald, Steffans, Malraux, Malcolm X, and others. *Staff*

21.015T ***Language, Culture, and Community: Primitive Culture and Ancient Civilization***
Prereq. ——
Year: U (1) 3–0–6
Study of primitive societies and cultures, e.g., the American Indians, in order to develop approaches to the description and analysis of universal aspects of human forms of life, such as habitat, economy, religion, social structure. Development of idea of the two senses of "culture" — anthropological and literary — by an intensive study of the two great cultural sources of Western civilization, the Hebrews and the Greeks. *Staff*

21.016T ***Language, Culture, and Community: Elizabethan England and Modern America***
Prereq.: 21.015T
Year: U (2) 3–0–6
Continuation of approaches of the first term in dealing with a Renaissance and a "modern" culture whose developing complexity of increasing "modernization" raise critical questions concerning the nature and function of "high culture," its relation to an "elite," the effects of the rise of science and technology, the decline of religion, the growth of "mass society" and "mass culture." *Staff*

21.017 ***Conflict and Community in America***
Prereq.: ——
Year: U (1) 3–0–6
Study of social conflict to reveal how Americans have thought and felt about problems of community and have sought to resolve questions of power, inequality and social injustice. Analysis of the role of different social groups in the process of social change. Consideration of forces and ideas which have led to peaceful change and political violence in American society. Reading of autobiography and fiction along with historical and sociological studies. *Staff*

21.018 ***Conflict and Community in America***
Prereq.: 21.017
Year: U (2) 3–0–6
Analysis of the changing structure of society, the sources of social conflict, and of the social and political imagination in twentieth-century America. Focus on the crises of the 1930's and the 1960's, and on response to these crises in politics, social behavior and literature. Current conceptions of community and reform along with the issues of power, class and race in contemporary America. *Staff*

21.019 ***God and Logic: The Philosophy of Religion in the West***
Prereq.: ——
Year: U (1) 3–0–6
Reading and discussion, from a contemporary philosophic standpoint, of traditional philosophical, literary, and scriptural texts bearing on the position of Judaism and Christianity in secular culture today. Survey of the modern critique of Western religion, followed by study of its origins in classical Greece and biblical Israel. Readings from Voltaire, Hume, Nietzsche, and Freud, as well as Homer, the tragedians, Plato, and the Bible. *Staff*

21.020 ***God and Logic: The Philosophy of Religion in the West***
Prereq.: 21.019
Year: U (2) 3–0–6
Continuation of 21.019. Intensive study of three sets of problems growing out of the first part of this sequence: (1) "theology," as represented by the ontological and cosmological arguments for the existence of God; (2) the psychology of "faith," as expounded in works on the phenomenology of the religious life and religious existentialism; (3) the "providential" pattern in human history as philosophically formulated by St. Augustine and later transformed by Kant, Hegel, and Marx. Other authors to be read: St. Anselm, Thomas Aquinas, Luther, Pascal, and Kierkegaard. *Staff*

21.03 ***Literature: Forms of A Major Theme***
Prereq.: One first-year Hum. sequence
Year: U (1, 2) 3–0–6
Study of the exercise of the literary imagination on some single major theme (e.g., love, death, guilt) as expressed in a variety of literary forms. Treatment of lyric, epic, drama, fiction, and essay will be concerned with such matters as the relation between forms and substance, the meaning of historical and social contexts, the roles of tradition and individual talent, the relation between the work and its audience. Special attention to the work of some single important writer in his handling of the theme in question. Theme varying from year to year. *(Credit given only for 21.03 or 21.031 or 21.11.)* *Staff*

21.031 ***Literature: Self, Nature and Society***
Prereq.: One first-year Hum. sequence
Year: U (1, 2) 3–0–6
Reading of literary works considered both as personal acts and public performances. Discussion concentrating on the relation between the author's personal sense of identity and the images of nature and society which help to shape his art. Consideration of the following major problems through study of a wide range of literary forms drawn from the tradition and the modern period: (1) the interaction between the perceived reality and the perceiving self; (2) the means by which drama, as communal art, affects its audience; (3) the significance of literary contributions to the present culture, seen in the context of social values and public response. *(Credit given only for 21.03 or 21.031 or 21.11.)* *Staff*

21.04 ***Philosophy: Classic and Contemporary***
Prereq.: One first-year Hum. sequence
Year: U (1, 2) 3–0–6
Problems of knowledge, moral choice, reality, and the existence of God. The nature of philosophical inquiry exemplified through the analysis of great texts. *Staff*

21.05 ***The Twentieth Century: Revolution and Totalitarianism***
Prereq.: One first-year Hum. sequence
Year: U (1, 2) 3–0–6
Introduction to history through the analysis of two complex twentieth-century phenomena: revolution (the Russian, Chinese, Cuban and Vietnamese Revolutions) and totalitarianism (Soviet and Chinese Communism, Nazi Germany). Historical analysis of the conditions that breed revolutions, the development of revolutionary ideologies, the roles of radical elites, the dynamics of revolutionary movements, and the characteristics of totalitarian movements and regimes. Study of various theories of revolution, including classical Marxism and its contemporary versions. Readings in primary sources, critical scholarly articles, and works of interpretation. *Staff*

21.06 ***The Twentieth Century: Society and Consciousness***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–6
Studies in historical perspective of characteristic forms of twentieth-century thought and consciousness, emphasizing the literature of psychoanalysis, social science, and existentialism. Case studies of social processes in America, Britain and Germany and of contemporary intellectual movements related to them. Reading from Alexis de Tocqueville, Hannah Arendt, Max Weber and Richard Hoggart; Freud, Malinowski and Erikson; Kierkegaard, Kafka and Sartre. *Staff*

21.07 ***Humanities Seminar***
Prereq.: ——
Year: U (1) 2–0–8
Interdisciplinary seminar on selected topic. (*Open only to seniors in Course* XXI-A *and Course* XXI-B, *Program 1.*) *Lamson*

21.071 ***History Seminar***
Prereq.: ——
Year: U (1) 2–0–8
Seminar on selected topic in history. (*Open only to juniors or seniors in Course* XXI-B, *Program 2.*) *Ralston*

21.072 ***Literature Seminar***
Prereq.: ——
Year: U (1) 2–0–8
Seminar on selected topic in literature. (*Open only to juniors or seniors in Course* XXI-B, *Program 2. Students registering for the Seminar should consult Course* XXI *Office.*) *Staff*

21.073 ***Philosophy Seminar***
Prereq.: ——
Year: U (1) 2–0–8
Seminar on selected topic in philosophy. (*Open only to juniors or seniors in Course* XXI-B, *Program 2.*) *Staff*

UNDERGRADUATE ELECTIVES

21.091 ***Philosophy and Scientific Method***
Prereq.: ——
Year: U (1) 2–0–4
Introduction to questions concerning the principles and methods of scientific activity, and their possible philosophical justifications. Problems of hypothesis formation and testing, induction, and probabilistic reasoning. Nature of scientific concepts, theories, and explanations, and the value of measurements, models, and ideals of natural order. Meanings of causality, determinism and free will, and the unity of science. The role of mathematics in science. *Graves*

21.092 ***Introduction to Moral and Political Philosophy***
Prereq.: ——
Year: U (2) 2–0–4
Study of background for contemporary moral philosophy. Readings from Hume, Mill, and twentieth-century moralists; consideration of moral relativism and moral skepticism. (*Not offered 1968–69.*) ——

21.094 ***Introduction to Contemporary Philosophy***
Prereq.: ——
Year: U (1) 2–0–4
Exploratory study of various trends in present-day philosophy: pragmatism, analytic philosophy, existentialism, psychoanalysis, Marxism, Zen Buddhism.
I. Singer, Graubard

21.095 ***Writing Tutorial***
Prereq.: ——
Year: U (1, 2) *Arr.*
Individual conferences by appointment for undergraduates who seek to increase the effectiveness of their writing. Determination of scope of conferences by instructor's assessment of work required, in light of the student's own goals for his writing. Not for credit. *Kaye*

21.096 ***The Writing of Prose***
Prereq.: ——
Year: U (1, 2) 2–0–4
Inquiry into the nature and practice of good writing. The writing of expository essays, autobiography, fiction and experimental prose to explore the process of fitting language to thought and feeling. Criticism of selected readings and student writings in class to determine the impact of the written word on the reader. Individual conferences central to the design of the subject; recordings, films, and video-tapes for added information on the processes of communication. *Kaye*

21.098 ***Preliterate Cultures***
Prereq.: ——
Year: U (2) 2–0–4
Sampling of readings about non-western cultures and societies in an effort to answer three questions: (1) how may an observer come to experience life in the same terms as an individual of a different culture? (2) how does an anthropologist go about studying situations foreign to his life experience? and (3) what is the relevance of anthropology for an understanding of our world? *Diskin*

SUBJECTS IN WRITING

21.10 ***Scientific and Engineering Writing***
Prereq.: ——
Year: U (1, 2) 2–0–4
Instruction basic to all types of communications that scientists and engineers are called upon to write, from abstracts to journal articles. Detailed analysis of the problems of conveying technical information to non-technical as well as to technical audiences. Term project involving a written paper on a technical or semi-technical subject and an oral presentation of the subject in class. *Rathbone*

21.101T ***Introduction to the Writing of Fiction***
Prereq.: ——
Year: U (1) 2–0–6
A small number of published stories read as examples of the ways in which writers solve certain technical or strategic problems. Emphasis on the needs and accomplishments of students whose manuscripts will be analyzed in both classroom discussions and individual conferences. (*Permission of instructor required.*)
J. S. Brown

21.102 ***The Writing of Fiction***
Prereq.: ——
Year: U (2) 2–0–6
Writing of fiction according to individual interests, supplemented by exercises in fictional techniques and critical reading of professional examples. Emphasis on analysis of students' manuscripts. *Cole*

21.103 ***The Writing of Poetry***
Prereq.: ——
Year: U (1) 2–0–6
Writing of poetry according to individual interests, supplemented by exercises in various poetic forms and critical reading of professional examples. Emphasis in class on analysis of students' manuscripts. (*Permission of instructor required.*) *Spacks*

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Descriptions

LITERATURE

For other subjects in literature in addition to those given below, see Special Interdisciplinary Subjects (especially 21.99T, 21.991, 21.996, 21.997, 21.998T), subjects in Writing, and subjects offered by the Department of Modern Languages and Linguistics.

21.11 *Literary Analysis*
Prereq.: One first-year Hum. sequence
Year: U (1, 2) 3–0–5
Reading of poems, stories, plays, and a novel to discover the capacities of literature and to suggest the properties that must be investigated in preparation for criticism. (*Open to those who have not taken 21.03 or 21.031.*) *Staff*

21.122 *Criticism and Culture*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Study of the critical tradition in which the experience of art and literature becomes central for understanding the nature of modern society. Authors to be read include Wordsworth, Carlyle, Ruskin, Pater, Yeats, Nietzsche, Freud, Eliot, Lawrence, Marshall McLuhan. (*Not offered 1968–69.*) *Kibel*

21.13 *The Epic*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Reading and discussion of samples of epic literature, from the tribal to the contemporary, to discover their ritual backgrounds and their services as intellectual and moral centers for their societies. *W. C. Greene*

21.14 *The Bible*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Readings in the literature of ancient Israel: study of comparative mythology, traditions from the "heroic" age, the divergent ideologies of the Davidic monarchy and the Mosaic covenant as preparation for understanding the exploitation of myth and tradition by the prophets and later poets. *Wakeman*

21.15 *Shakespeare*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1, 2) 3–0–5
Reading and discussion of ten selected plays of Shakespeare, especially tragedy, in an effort to understand Shakespeare's work as dramatic and poetic expression of Renaissance and Elizabethan views of man. Study of the traditional and innovative qualities of Shakespeare's art and development in their relation to the theater and drama of his time and to later treatments in the modern theater and in films. Independent study of a contemporary of Shakespeare, Marlowe, Dekker, Jonson, or Webster; some exercises in criticism of current performances. *MacIsaac, Lamson*

21.16 *Chaucer*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Reading and discussion of *The Canterbury Tales* and *Troilus and Criseyde.* (*Not offered 1968–69.*) *Lamson*

21.17 *Literature of the English Renaissance*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Rise and development of English poetry and prose in the sixteenth and early seventeenth centuries, with some attention to the drama. Problems of artistic and social tradition and convention of the Renaissance and their relationship to English innovation and achievement. Reading and discussion of Marlowe, Sidney, Spenser, Shakespeare, Bacon, Jonson, Donne, Browne and other selected writers. *Lamson*

21.24 *Nature of Poetry*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
A subject to stimulate understanding and appreciation of essentials of poetry. Discussion of selected works of poets from Chaucer to contemporary Americans in terms of the variety of influences shaping them — social, psychological, literary, technical. Lectures, readings, and informal discussions by poets in the vicinity. (*Not offered 1968–69.*)

21.27 *Narrative Fiction*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Studies in European Realism: An attempt to define the tradition of psychological realism in the novel as a unique fusion of comic plot and tragic conception of character. Works by Balzac, Stendhal, Flaubert, Dostoevsky, Tolstoy, Gide, Kafka and Camus. *Kibel*

21.276 *The Short Story*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
The modern short story as a form of literature, approached through a comparative study of various contrasting narrative forms, such as parable, folk legend, fable, Oriental tale, and through a close reading of Chekhov, Joyce, Hemingway and others in the modern canon, in Europe and America. Attention paid to the philosophic and social bases of the short story as a flourishing form in the past century, and to its role as predecessor and competitor to narrative devices being developed in the newer media. Numerous short papers required. (*Permission of instructor required.*) *Cole*

21.28 *Theatre Arts: Elementary Stagecraft and Production Studies*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1, 2) 3–0–5
Introduction to the techniques of modern theatre as a means of realizing the thematic content of drama. Tutorial discussions and laboratory exercises in the theatre. Individual 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*

21.281 *Drama and Community*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Examination of drama as a fundamentally communal experience in its inception, production, and final effects; study of local productions and of movies, when relevant; comparison of the political focus of classical Athenian drama with various contemporary attempts to reassert a sense of community in the audience. *Gurney*

21.282 *Modern Drama*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Close reading of modern dramatists. Plays by Ibsen, Chekhov, Shaw, O'Neill, Wilder, Hellman, Williams, Miller, Ionesco, Beckett, Genet, and others. Approved practical projects in theatrical techniques accepted in lieu of term papers. (*Limited enrollment.*) *Everingham*

21.284 *Comedy*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Close reading and discussion of works which have made men laugh, along with various theories which attempt to explain why. (Aristophanes, Plautus, Apuleius, Chaucer, Shakespeare, Molière, Sheridan, Wilde, Shaw, Twain, and various contemporary writers; Aristotle, Cornford, Frye, Kierkegaard, Meredith, Freud, Bergson, Langer, and others.) (*Permission of instructor required.*) *Gurney*

21.285 ***American Folklore***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Folklore as popular historical documentation of experiences and beliefs of the American people. Supplementary readings in formal history. Examination of use of folk materials in music, drama, literature, art. (*Limited to 25 students.*) *T. Wood*

21.29 ***Dostoevsky, Tolstoi, Chekhov: Russia and the Modern Age***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Studies of artistic vision in modernizing Russia. Reading and analysis of *The Brothers Karamazov, The Possessed, Anna Karenina, The Death of Ivan Ilyich, The Seagull, The Three Sisters,* and shorter works by each of the three authors. Discussion with critical and biographical readings of the relation of artistic works to social and cultural processes. All works in English translation. (*Not offered 1968–69.*) *MacMaster*

21.301 ***Non-Western Literature***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 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 1968–69.*) *W. C. Greene*

21.302 ***Chinese Literature***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Reflection of Chinese culture in literature from earliest times to the present. Reading to discover the aims of fiction and poetry and how they were realized in China, providing a foundation for a more objective approach to Western literary traditions. Either 21.301 or 21.951 desirable preparation, but not required. *Sivin*

21.31 ***Four Irish Writers: Synge, Yeats, Joyce, and O'Casey***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Study of four different ways in which the Irish artist responded to a crisis of history and made of his works of art either an involvement in revolution or an insistence upon an aesthetic consciousness of human experience. (*Not offered 1968–69.*) ——

21.312 ***The Confession in Literature***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Study of some of the great confessional works in order to understand changes that have occurred in the conception of the self during the past 1,500 years. Readings include Augustine's *Confessions*, Montaigne's *Essays*, Rousseau's *Confessions*, fictional confessions like Dostoevsky's *Notes from Underground*, Svevo's *Confessions of Zeno*, and autobiographical poems. *Goodheart*

21.313 ***Major Authors: Marcel Proust***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Work of a different author each term. May be repeated with permission of instructor in charge. *Remembrance of Things Past* as a focus for some contemporary difficulties in life as well as in art, and as an instance of the relationship between the modes of fiction and autobiography. Related readings in other authors as the class finds them necessary. *Kampf*

21.314 ***Major Authors: William Butler Yeats***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Work of a different author each term. May be repeated with permission of instructor in charge. Examination of Yeats' writings, principally the poetry, to determine the range and types of connections possible between art, politics, and personal experience. Incidental reading of other authors. *Bornstein*

21.315 ***History of the English Language*** **(A)**
Prereq.: ——
Year: G (1) 3–0–9
Selected topics in the history of English syntax, morphology and phonology from Old English to the present, formulated within an attempt at a general theory of linguistic change. Some knowledge of Old and Middle English desirable. (*Open to undergraduates by permission of instructor.*) *O'Neil*

21.317 ***Studies in Literature and National Values***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Examination of American and Russian self-images as they are embodied in their literary traditions. Use of selected novels and short stories to elucidate and compare the values by which each nation defines itself. *Dworsky*

21.35T ***Social Vision in Literary Art: Shaw, Lawrence, Faulkner***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Reading in depth of three major writers, with emphasis on the varieties of social consciousness which affect dramatic and narrative form. Works to be read include: George Bernard Shaw's *Widower's Houses, Mrs. Warren's Profession, Man and Superman, Heartbreak House, Back to Methuselah;* D. H. Lawrence's *Sons and Lovers, Women in Love, The Plumed Serpent, St. Mawr, Lady Chatterley's Lover;* William Faulkner's *The Sound and the Fury, Absalom! Absalom!, Go Down Moses, The Hamlet.* *Merritt*

21.36 ***Individual and Environment in Modern Literature***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Changing relation between the individual and his world from the Romantics to the present, in terms of efforts to break down what Pater called the "thick walls of personality" which separate the individual from his social and natural environment. Reading and discussion of novels by Bellow, Dickens, Forster, and Hemingway; the philosophy of Buber, Hazlitt, and Pater: the poems by Arnold, Browning, Keats, Shelley, Stevens, Wordsworth, and Yeats. (*Not offered 1968–69.*) *Bornstein*

Special Seminars

(Work in the following subjects will be done in close association with the instructors. Each is open to all students with the permission of its instructor.)

21.38 ***Sources of Modernism***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Some current uses of the concept of literature as self-expression; the impact of its corollary — sincerity as a criterion of artistic excellence — on our experience of works of art. Authors to be read: Genet, D. Lessing, Swift, Sterne, Constant, and some anonymous poets. (*Not offered 1968–69.*) *Kampf*

(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.

21.381 ***Literature Today***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Critical confrontation with examples of contemporary poetry, fiction, and drama; emphasis on the relation of immediate cultural themes to traditional sources. Study of the current work of such figures as Bellow, Lowell, Pinter, Ginsberg, Nabokov, Mailer, and Sarraute. Some classes taught by writers themselves. *Spacks*

21.382 ***The Lyric Form of Consciousness***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Psychological and literary inquiry into the nature of the self as it is expressed in lyric poetry and studied in the literature of psychology. Special attention to religious, artistic, and schizophrenic language. Poets of the English tradition from the seventeenth century Metaphysicals to the present. Psychologists: William James, Freud, Fromm, Jung, Piaget, A. F. C. Wallace, Norman O. Brown, Abraham Maslow, and R. D. Laing. (*Enrollment limited to 15 upperclassmen. Not offered 1968–69.*) *Thompson*

21.384 ***Linguistics and Literary Study*** **(A)**
Prereq.: ——
Year: G (2) 3–0–9
Study of the formal properties of the language of literature. Consideration of the insight that linguistic theory gives into the development of a general theory of literature. (*Limited to 15 students. Undergraduates admitted only by permission of instructor.*) *O'Neil*

21.391 ***Special Topics in Literature***
Prereq.: Any two subjects in literature
Year: U (1) *Arr.*
Open to qualified students who wish to pursue special studies or projects with members of the Literature Section. Students electing this subject must consult the Chairman of the Section. *Staff*

21.392 ***Special Topics in Literature***
Prereq.: Any two subjects in literature
Year: U (2) *Arr.*
Open to qualified students who wish to pursue special studies or projects with members of the Literature Section. Students electing this subject must consult the Chairman of the Section. *Staff*

HISTORY

Economic-Technological

21.41 ***Pre-Industrial Europe***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Historical and analytical study of the development of European economy and society before industrialization (1100-1650). Emphasis upon the changing relations between agrarian and commercial economies, rural and urban societies, local and interregional operations. (*Not offered 1968–69.*) *Watson*

21.411 ***History of Engineering***
Prereq.: One first-year Hum. sequence
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*

21.412 ***History of Engineering***
Prereq.: One first-year Hum. sequence
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*

21.414 ***History of Materials***
Prereq.: One first-year Hum. sequence
Year: U (1) 2–0–6
Study of man's knowledge of materials and attitude toward them in all ages from the discovery of ceramics to modern materials science. Materials as a bridge between art, science and engineering. Emphasis on use of original sources and artifacts. *C. S. Smith*

21.415 ***Technology and Economic Growth***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Growth of technology in the modern world in its relationship to economic and social change. Craft technology; industrialization — invention, origins of mass production and interchangeable parts, power sources, transportation, mechanization of agriculture, technology and large-scale enterprises, new industries. *Woodbury*

21.421 ***Development of American Economic Institutions***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Topical study of the development of the American economy from 1800 to the present, concentrating on about four of the following topics: Alexander Hamilton; the early New England factory town; the plantation-slave economy; the westward movement; the American farm; the labor union; the automobile industry; the failure of an economy in the 1930's, and the New Deal. *Bryant*

21.422 ***History of Transportation in the United States***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Study of new modes of transportation such as the canal, the steamship, the railroad, the automobile, and the airplane — their technical development, their effect on the American economy and society, and the evolution of new institutions for the management and control of the business of transportation. *Bryant*

21.424 ***The Businessman in American History***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Study of the changing roles, images, and characterizations of businessmen in America from the colonial period to the present, with special emphasis on tensions between the traditional and innovative in practices, structure, perspectives and values. Readings in history, biography, fiction and critical and popular periodicals. *Hartley*

21.426 ***History of Technology in the United States***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
An introduction to the development of technology in the United States as interwoven with its economic and social background and influence. Representative topics: cotton, slavery, and Eli Whitney; interchangeable manufacture and the "American system"; McCormick and prairie agriculture; Oliver Evans and automation in grain milling; Samuel Colt and firearms; American machine tools; Howe, Singer, and the sewing machine;

American shipbuilding — the clipper ship and the ironclad; petroleum — Drake and Rockefeller; the Wright Brothers and aviation; Ford and the automobile.
Woodbury

Social-Cultural

21.452 *Introduction to Social Anthropology*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
The organizational aspects of human groups. A cross-cultural approach to the study of kinship, age-grading, caste and class, and their relevance for technology, ideology and economics. Examination of the social and cultural frameworks in anthropological theory through the use of field reports and monographs. *Guggenheim*

21.454 *Near Eastern Archaeology: The Foundations of Civilization*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
A study of the "Urban Revolution" and the achievement of the earliest cities in the ancient Near East. Relationships between political authority, technology, economic structure, myth, and art in Mesopotamia, Egypt, and Anatolia. Reading combining study of original texts with archaeological reports, and work in local museums.
Steinberg

21.455 *Peasant Society*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Definition of the peasant as a social type; consideration of so-called centrifugal-centripetal forces that help shape a given society. Historical factors in the cases of Mexico, Colombia, Jamaica, southern Italy and Malaya. The nature of economic links between the peasant and modern society. Cultural, historical and personality factors in economic development. *Diskin*

21.456 *Economic Anthropology*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Economic aspects of culture and society. Modes of exchange, distribution, and production in non-monetized societies. Consideration of prestation, barter, and peasant markets as mechanisms of social articulation. Examples from New Guinea, Malaya, Mexico, and Africa. The notions of scarcity and maximization examined for their universality. The dual economy debate and economic development discussed. (*Not offered 1968–69.*) *Diskin*

21.459 *Cultures and Societies of Mexico*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Historical background beginning with the early archeological horizons and the Spanish conquest studied up to present time. Case studies of groups at different levels of development, with emphasis on Mexico and Guatemala. Analysis of social change in the context of historical tradition. *Diskin*

21.463 *The Emergence of Modern Africa*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Examination of problems concerning the social and cultural, economic, and political development of tropical Africa from earliest times to the modern period. Interdisciplinary approach, with special emphasis on the findings of archaeology, ethnobotany, linguistics and ethnohistory. Emphasis on indigenous invention as well as the stimulus of contact with Arabia, the Orient, and Europe. The slave trade and the growth of Europe's awareness of Africa. *Rotberg*

21.473 *Rome: Reality and Idea*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Rome from city-state to world-empire. Structure and function of public power in the "classical" republic. Reasons for, and mystique of, Rome's ascendancy: conservatism and improvisation as political ways of life. Revolutionary impact upon, and of, Greek political theory: the captive captor. The Roman revolution and its outcome: world-empire and peace. The unwritten constitution as reality and facade. The question of the "decline and fall": survey and assessment of rival views. The religious, economic, political, and social factors. Byzantium and the Roman legacy. Readings in Roman historians and poets and in secondary works such as Syme, Rostovtzeff, and Gibbon. *Reiche*

21.475 *Culture and Society in Medieval Europe*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Interplay of intellect and society circa 284–1350 A.D. Role of Christian world view in orthodox and heretical manifestations studied against background of social change and political conflict. Topics discussed: continuity from late Roman to early medieval culture; mystic and rational currents in philosophy; Carolingian and Ottonian "rebirths"; idea of a Holy Roman Empire; meaning of scholasticism; and problem of disintegration of medieval life forms. Individuals discussed: Augustine, Bede, Alcuin, John of Salisbury, Aquinas, Eckhardt, and William of Ockham. Romanesque and Gothic art and Latin, Romance, and Germanic literatures surveyed. Concepts of "ancient," "medieval," and "modern" examined. (*Not offered 1968–69.*) *Herzstein*

21.476 *The Italian Renaissance*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Comparative studies in the development of Italian society and its culture from the generation of Dante to that of Machiavelli, with principal emphasis on Florence and Venice. Reading drawn largely from documents and source materials written by merchants, lawyers and magistrates; artists, scholars and men of letters. (*Not offered 1968–69.*) *Douglas*

21.478 *The Northern Renaissance and the Reformation*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Historical change in the structure of society, the economic order and politics, studied in relation to various themes of complaint, protest and reform. Reading in the works of Thomas More, Machiavelli, Luther, Calvin, Rabelais, Montaigne and Cervantes. *Douglas*

21.482 *Social Criticism in America From Tocqueville to Riesman*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Study of the thought of the following social critics (singling out four or five for detailed scrutiny), and through their work, study of changes and continuities in American values and society since the Colonial period: Tocqueville, Veblen, Brooks Adams, Randolph Bourne, C. Wright Mills, Paul Goodman, David Riesman, Robert Merton, Seymour Lipset, Dwight McDonald, Norman Mailer. (*Not offered 1968–69.*) *Kaledin*

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21.483 ***Dissent and Reform in Twentieth-Century America***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Study of the politics of reform, and of the social, psychological and ideological characteristics of dissenting movements in twentieth-century America. Topics included: the continuing current of "orthodox reform" (the Progressive movement, the New Deal and its latter-day versions); the labor movement and reform; varieties of radical dissent (the failure of socialism in the U.S., the Communist movement in America, dissent on the right from the '30's to the John Birch Society, and on the left from the '30's to the "New Left"); the Negro Revolt of the '50's and '60's. Comparison with social reform movements and dissent in other societies. *Kaledin*

21.484 ***The Negro, The Ghetto and the Riots of the Sixties***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Lectures and readings about the 1960 riots, the Negro ghettos and the relationship between them. Among the topics to be considered: riot participation, police practices, economic deprivation, consumer exploitation, Negro leadership, and public policy. Emphasis on the techniques of comparative history and the social sciences in approach and assignments. *Fogelson*

Intellectual-Scientific

21.512 ***Science and Natural Philosophy in Chinese Tradition***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Foundation, through study of the only major non-Western scientific tradition, of a comparative approach to the origins and development of conceptions and theories. Study of general ideas and disciplinary approaches. Emphasis on both the essential character of science and its culturally conditioned style. Readings in primary sources, including unpublished translations. (*21.951 and/or 21.701 desirable as preparation, but not required.*) *Sivin*

21.515 ***Intellectual History of Modern Europe***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Intellectual history of the period from 1760 to the present, focusing on political and social thought, but in terms of the interplay of ideas from different fields, and of ideas and events. Consideration of such topics as romanticism, industrialism, and socialism; the increase in awareness of the self; the rise of historicism; the nature of ideology; the concepts of classes, masses, and races; and the nature of imperialist and totalitarian thought. Presentation focused, wherever possible, upon important individuals who epitomize a way of thinking and feeling. *Mazlish*

21.517 ***Russia: Orthodoxy, Autocracy, and Rebellion***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Comparative historical analysis of Russian radical social thought (communist anarchism, populism, socialism, utopianism in general) and action before the advent of Bolshevism. Analysis of social structures, historical experiences, religious and political traditions in Russia, in an effort to discover reasons for the relative prominence of radicalism in modern Russian as compared to modern Western thought. Study of such thinkers as Herzen, Chernyshevsky, Bakunin, Lavrov, Tkachev, Nechaiev and of revolutionary circles and conspiracies inspired by them. (*Not offered 1968–69.*) *MacMaster*

21.519 ***Ideologies of Elite and Violence***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Victory of liberal-democratic institutions and growth of antirationalist patterns of thought and feeling in emergent mass society: a confrontation; integral nationalism, imperialism, racism, and antisemitism — the new dynamic Right; syndicalism and Bolshevism reasserting the ideology of total revolution against democratic and revisionist socialism; the encounter between extreme left and extreme right in pre-1914 France and Italy; the ideological polarization during and after World War I; the anatomy of totalitarian revolutions in the twentieth century. *Talmon*

21.522 ***Marx, Darwin, and Freud***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Historical and critical study, in depth, of three attempts to investigate the natural and cultural development of man and society, treated as a problem in intellectual history, history and philosophy of the cultural sciences, and social thought. *Mazlish*

21.524 ***History and Psychoanalysis***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Attempt to inquire into the psychological, especially the psychoanalytic, aspect of historical events and persons. First part: examination of various theories and techniques that have already been employed by historians and psychologists; e.g., readings in Erikson, *Childhood and Society* and *Young Man Luther*, and O. Mannoni, *Prospero and Caliban: the Psychology of Colonization*, etc. Second part: reports by members of the class on their own attempts to study an event or person in psychohistorical terms. (*Permission of instructor required.*) *Mazlish*

21.531 ***American Intellectual History***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Study of important case specimens in the dialogue between "conservatives" and "liberals" from the Founding Fathers to the Radical Right and New Left. Seminar-type discussion of the role of major figures such as Jefferson, Calhoun, Emerson, Sumner and Veblen and of major forces such as industrialization, urbanization and immigration in the shaping of American ideas and values. *Hartley*

21.532 ***American Ideas and Institutions***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Historical study of the development of a free, tolerant, and pluralistic society in the United States. Nineteenth-century dissenters and utopians, especially the Transcendentalists and the Mormons. The tradition of civil liberties in America, and the use of the Constitution to promote freedom and tolerance. Pragmatism (Peirce James, Dewey, and Holmes) as a peculiarly American rationale for individualism, pluralism, and social reform. *Bryant*

POLITICAL — DIPLOMATIC

21.541 ***The American Revolution***
Prereq.: 17.01 or 21.05 or 21.06
Year: U (1) 3–0–5
Analysis of the social, political and ideological roots of the American Revolution; of the revolutionary movement itself; and of the formation of the new nation and its Constitution. Consideration of the changing image of the Revolution throughout our history, from accounts written by revolutionary partisans to the most recent interpretations. Comparison of the American with other major Revolutions. (*Not offered 1968–69.*) *Kaledin*

21.542 ***Chinese Foreign Relations in the Nineteenth and Twentieth Centuries***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Study of Chinese foreign policy in the light of the Chinese view of the rest of the world and of world policies towards China. Attention to the attempt of a dominant and self-contained body-politic to develop a modern relationship with the outer world, and the significance of that attempt for Western relations with China. Special emphasis on the examination of translated Chinese texts on foreign relations. (*Not offered 1968–69.*) *Watt*

21.543 ***China, Japan, and the West***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Relations of the West with China and Japan and the revolutionary ferment set up in the Far East by these contacts. Study of the traditional cultures of China and Japan in their geographic settings. Emphasis on tracing and seeking to explain the processes by which the self-sufficiency and isolation of China and Japan were broken down; development of resulting cultural changes, both planned and spontaneous. *Mahoney*

21.544 ***France: The Modernization of a Developed Society***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Examination of the problems of modernization in an already highly advanced society. Emphasis on those factors which since the beginning of the industrial era have contributed to the slowness in the modernization of France as compared to certain of her neighbors. Study of the periodic efforts of the French state since the time of Napoleon to accelerate the process. *Ralston*

21.545 ***War and the Military Institutions of the Modern State***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Examination of the evolution of military institutions of the modern state in the light of the changing forms and modes of war since the eighteenth century. Stress on the interacting relationship between the military institutions of a state and its political institutions and their effect on civil society. *Ralston*

21.547 ***Nationalism and Politics in Central Europe from the French Revolution to the Third Reich***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Awakening of national consciousness among Magyar, Czeck, German and Pole, and the meaning of this modern development for the Hapsburg monarchy and Europe. Study of the interplay of nationalism, economic development, international politics, and social traditionalism in this area from 1804 through 1945, treated as a model for comprehension of "contemporary history." (*Not offered 1968–69.*) *Herzstein*

21.548 ***Vienna and Versailles***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Two modern attempts to construct an enduring peace for Europe and the world following, respectively, the Wars of the French Revolution and Napoleon and World War I. Comparison of the ideas, institutions, and personalities dominating the architects of Vienna with their counterparts a century later at Versailles. *Mahoney*

21.549J ***The Impact of the West on Africa***
(Same subject as 17.62J)
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Examination of the ideological, political, and economic bases of imperialism and colonial rule; the ending of the slave trade, the exploration of Africa, the new evangelism, the partition of Africa, the methods of colonial rule, and the response of Africans thereto during the nineteenth and twentieth centuries. *Rotberg*

21.552 ***Russian Revolution and the Soviet Union***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Comparative historical analysis of Russia's modernization. Study in depth of the nature and origins of Bolshevism, the relationship of the 1917 revolutions to basic historical processes in Russia, the revolutions themselves, Stalin and the origins and structure of the Communist autocracy. Attention directed to the problem of evaluating the Soviet historical experience in the light of recent developments in the U.S.S.R. and the modern world (including the Sino-Soviet dispute). *MacMaster*

21.554 ***Spanish Civil War, 1936-39***
Prereq.: 21.05 or 21.06
Year: U (1) 3–0–5
Study of the process by which the Civil War in Spain transformed existing conflicts in Spanish society — between republicans and monarchists, civil and military authorities, intellectuals and clerics, workers and capitalists, peasants and landowners — into a European struggle between democracy and reaction, atheism and Christianity, Communism and fascism. Examination of Spain as the testing ground of European military and political powers and as the battlefield for competing twentieth-century ideologies. Readings from contemporary sources and recent studies. *Watson*

21.556 ***Soviet-American Diplomacy***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Study of the foreign policies and diplomatic interaction of the two powers beginning with nineteenth-century patterns of Tsarist and American diplomacy. Case studies which permit detailed examination of the origins of Bolshevik diplomacy with a view toward continuity and change; the formation of America's stance on Soviet Russia; parallels between the two societies during the interwar period: isolationism, messianism, and the drive for security; the themes of conflict and cooperation in World War II, followed by the "Cold War" and the bipolarization of Europe; and the emergence of a new diplomacy. Emphasis on a comparison of the two nations, their parallel problems and instances of direct confrontation. *Clemens*

21.558 ***Reconstruction of Europe, 1945-65***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
The Marshall Plan, the Iron Curtain, NATO, the Fourth and Fifth Republics, Italy, Germany, Great Britain. Towards a United States of Europe: the New Technicians; the Common Market; EFTA; Euratom. *Mahoney*

21.574 ***Nineteenth Century European Liberalism: Its Decline and Transformation***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Examination of nineteenth-century European liberalism as it was embodied in the political institutions and politi-

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cal practices of such states as Great Britain, France, Germany, Italy, and Austria-Hungary. Origins of the liberal ideology, and its underlying assumptions about man and society. Forces leading either to its breakdown or transformation in the decades prior to World War I. (*Not offered 1968–69.*) *Ralston*

21.576 *Varieties of Fascism: Origins and Comparative Development in Germany and France, 1900–1945*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Study of a major modern theme on both the intellectual and sociopolitical levels, using the comparative method. Fascism in France and Germany as a study in comparative modernization, viewed in part as a response to economic and social change in the period 1870–1945. Focus on the quasi-failure of fascism in France and its success in Germany after 1932, with this central theme posed as a basic question. *Herzstein*

21.577 *Modernization in Chinese State and Society*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Study of the transformation of an Imperially administered agrarian society. General theme: problems involved in the modernization of non-Western countries. Specific study of the nature of change in Chinese state and society, and the modern Chinese attempt to direct social change through application of developmental policies. *Watt*

21.591 *Special Topics in History*
Prereq.: Any two subjects in history
Year: U (1) *Arr.*
Topics in history not included in other subjects. Student electing this subject must consult the Chairman of the Section. *Staff*

21.592 *Special Topics in History*
Prereq.: Any two subjects in history
Year: U (2) *Arr.*
Topics in history not included in other subjects. Students electing this subject must consult the Chairman of the Section. *Staff*

PHILOSOPHY

21.611 *History of Philosophy I*
Prereq.: 21.04
Year: U (1) 3–0–5
Survey of ancient philosophic thought. Emphasis on Plato and Aristotle. *Brody*

21.612 *History of Philosophy II*
Prereq.: 21.04
Year: U (2) 3–0–5
Philosophic thought from the Renaissance through the Enlightenment. Emphasis on Descartes, Locke, and Hume. *Cartwright*

21.613 *Classical Philosophy*
Prereq.: One 1st Yr. Hum. Sequence
Year: U (2) 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*

21.617 *Philosophy of History*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Examination of philosophical questions arising from the critical analysis of historical writing, including the problem of explanation and laws, the nature of narrative, rationality and the explanation of human action, the possibility of substantive theories of history, and the relation of history to the social sciences. Readings from classical and contemporary writers. (*Not offered 1968–69.*) *Graubard*

21.618 *Social Theory from Marx to the Present*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Investigation of some of the major figures in the development of modern social theory — Marx, Weber, Durkeim, Mannheim, Freud, Parsons, analyzed with respect to certain key substantive questions, the role of ideas in social action (the theory of ideology). Second dimension of inquiry: the investigation of the philosophical and methodological questions related to the social sciences and history. Contemporary extensions within the various social sciences of the theoretical approaches developed by the classical social theorists. *Graubard*

21.641 *Symbolic Logic*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Introduction to the aims and techniques of formal logic. The logic of truth-functions and quantifiers. Formal systems: consistency and completeness. The decision-problem for a formal system. Applications of formal logic, the place of logic in philosophy. *James F. Thomson*

21.642 *Philosophy of Logic* (A)
Prereq.: ——
Year: G (2) 3–0–9
Relations between logical operators and their ordinary language counterparts; questions about logical form, logical truth, analyticity, reference, presupposition, and "ontological commitment"; times and tenses; problems about modality and identity. (*Primarily for graduate students in philosophy; others admitted only by permission of instructor.*) *Brody*

21.643 *The Logic of Questions* (A)
Prereq.: ——
Year: G (2) 3–0–9
Discussion of recent literature on erotetic logic (the logic of questions). Examination of problems which arise in the attempt to formalize the logic of questions. Relation of this logic to some problems in the philosophy of science. (*Primarily for graduate students in philosophy; undergraduates who have taken 21.04, 21.641 and 21.647 may be admitted by consent of the instructor. Not offered 1968–69.*) *Bromberger*

21.644T *Ethics*
Prereq.: 21.04
Year: U (2) 3–0–5
Systematic study of some central problems in ethics, such as the relation between fact and value, the nature of obligation, the relevance to moral evaluation of pleasure, desire, intention, etc. *Judith J. Thomson*

21.647 *Theory of Knowledge*
Prereq.: 21.04
Year: U (1) 3–0–5
Study of problems concerning our concept of knowledge, our knowledge of the past, our knowledge of the thoughts and feelings of ourselves and others, and our knowledge of the existence and properties of physical objects in our immediate environment. *Levensky*

21.651 *Moral Philosophy* (A)
Prereq.: ——
Year: G (1) 3–0–9
Systematic study of some problems of moral philosophy. Special attention to the justification of moral evaluation of actions and the relevance to this of intentions, motives, and consequences. Readings chiefly from contemporary sources. (*Primarily for graduate students in philosophy; undergraduates who have taken 21.04 or 21.647 may be admitted by consent of the instructor.*) *Judith J. Thomson*

21.652 *Problems in Ethics*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Study of problems in the theory of value as relevant to both Existentialist and Analytical philosophies; e.g., the nature of choice, the analysis of affective language, the phenomenology of moral judgment. Readings chosen in relation to interests of individual students.
I. Singer

21.653 *Nature and Justification of Liberty*
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Problems connected with liberty and coercion in society. The question whether there is a presumption in favor of men being free, and how such a presumption could be justified or rebutted. Examination of such notions as interference, constraint, compulsion, and coercion.
Dworkin

21.654T *Responsibility in Law and Morality* (A)
Prereq.: ——
Year: G (2) 3–0–9
Examination of concepts such as purpose, causation, act and omission and their bearing on issues of responsibility in law and morality. (*Primarily for graduate students; undergraduates admitted by permission of instructor.*) *Dworkin*

21.656 *Problems of Explanation and Theory Formation* (A)
Prereq.: ——
Year: G (2) 3–0–9
Problems about the nature of explanation, the evaluation of competing explanations, and the relation of observation to theory. (*Primarily for graduate students in philosophy; undergraduates who have taken 21.04 and 21.641 may be admitted by consent of the instructor.*) (*Not offered 1968–69.*)
Bromberger

21.657 *The British Empiricists* (A)
Prereq.: ——
Year: G (1) 3–0–9
Studies in the writings of Locke, Berkeley, and Hume. (*Primarily for graduate students in philosophy; undergraduates who have taken 21.04 and 21.647 may be admitted by consent of the instructor.*) (*Not offered 1968–69.*) *Bromberger*

21.658 *Kant* (A)
Prereq.: ——
Year: G (2) 3–0–9
Critical examination of the logical, epistemological, and metaphysical doctrines of Kant. Main text: *The Critique of Pure Reason.* Some attention to his views in the *Prolegomena*, the *Inaugural Dissertation*, and some of his early writings. (*Primarily for graduate students in philosophy. Undergraduates admitted by permission of instructor.*) *Brody*

21.659 *Problems of Knowledge* (A)
Prereq.: ——
Year: G (2) *Arr.*
Study of problems concerning the foundation of knowledge, with special attention to our concepts of evidence, belief, doubt, knowledge, certainty and philosophy.
Levensky

21.661 *The Continental Rationalists* (A)
Prereq.: ——
Year: G (1) *Arr.*
Studies in the writings of Descartes, Spinoza and Leibnitz. (*Primarily for graduate students in philosophy; undergraduates admitted by permission of instructor. Not offered 1968–69.*) *Cartwright*

21.662 *Probability and Evidence* (A)
Prereq.: ——
Year: G (2) 3–0–9
Some questions about the concept "probable" and about the interpretation of probability statements. Examination of the so-called philosophical theories of probability. Relations between the concepts "probable," "reason," and "evidence." (*Primarily intended for graduate students; undergraduates may be admitted by consent of the instructor. Not offered 1968–69.*) *James F. Thomson*

21.663 *Philosophy and the Life Sciences* (A)
Prereq.: ——
Year: G (2) 3–0–9
Selected concepts and empirical findings in the life sciences examined for their possible relevance to various problems of philosophy: e.g., current psychiatric and ethological theories about instinct or unlearned behavior studied in their relation to philosophical questions about moral, aesthetic, and religious experience. (*Undergraduates admitted by permission of instructor.*) *I. Singer*

21.664 *Analytic Philosophy* (A)
Prereq.: ——
Year: G (2) 3–0–9
Examination of some major tendencies in recent and contemporary philosophy such as positivism, the late philosophy of Wittgenstein, and Oxford philosophy. Special reference to theory of knowledge and philosophy of language. (*Primarily for graduate students in philosophy; undergraduates admitted by consent of instructor.*) *Fodor*

21.665 *Background of Contemporary Philosophy* (A)
Prereq.: ——
Year: G (1) 3–0–9
Frege; the early philosophies of Moore and Russell, and associated continental movements: logical atomism. (*Primarily for graduate students; undergraduates admitted by permission of instructor.*) *Cartwright*

21.666 *Wittgenstein* (A)
Prereq.: ——
Year: G (2) 3–0–9
Examination of certain views proposed in Ludwig Wittgenstein's *Philosophical Investigations* and his other writings. (*Primarily intended for graduate students; undergraduates may be admitted by consent of the instructor. Not offered 1968–69.*)
James F. Thomson, Fodor

21.668 *Philosophical Anthropology*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Philosophical reflection on findings of the behavioral sciences that bear on man's nature. Critique of Western philosophy's attention to man as contemplative knower to the neglect of man as agent whose existence is constituted by his relations with others. Cross-cultural comparison of the way Western, East Asian, and South Asian civilizations have emphasized, respectively, the individual, social, and universal aspects of self. Experimental attempts to create basic human encounters which can provide an experiential base for the themes considered. (*Limited enrollment. Advance permission of instructor required.*) *H. Smith*

(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.

Descriptions

21.671 *Philosophy of the Arts*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Investigation of problems concerning identifying, interpreting, and evaluating works of art. Special attention to experimental forms of literature, film, and music.
Levensky

21.672 *Philosophy in Literature*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Philosophical concepts as an aesthetic component in literature. Works of Romantic and Existentialist literature studied in relation to moral, religious and psychological problems about love, hatred, despair, etc. (*Limited enrollment.*)
I. Singer

21.676J *Philosophical Psychology* (A)
(Same subject as 9.595J)
Prereq.: ——
Year: G (2) 3–0–9
Place of psychology in the sciences. Nature of psychological explanation. Materialism and behaviorism. Problems concerning simulation of human behavior. (*Not offered 1968–69.*)
Fodor

21.677 *Metaphysics* (A)
Prereq.: ——
Year: G (1) 3–0–9
Examination of basic metaphysical concepts such as individual, substance, event, person, and kind. This year emphasis on Strawson's *Individuals*. (*Primarily for graduate students; undergraduates admitted by permission of instructor.*)
Brody

21.691 *Philosophies and Religions of Asia*
Prereq.: One first-year Hum. sequence
Year: U (2) 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

21.692 *Religious Philosophy in the West*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
An examination of the conceptual components of Judaism, Christianity, and Islam. Principal historical developments and the contemporary scene. (*Not offered 1968–69.*)
H. C. Smith

21.693 *Philosophy of Religion*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Object and method of religious philosophy. Relation to theology, phenomenology, and the history, psychology, and sociology of religion. Historic and contemporary meaning of key religious concepts and evaluation of central religious claims. (*Not offered 1968–69.*)
H. C. Smith

21.701 *Science and Philosophy from Archaic Antiquity to Copernicus*
Prereq.: One first-year Hum sequence
Year: U (1) 3–0–5
Development of the philosophy of nature from the earliest Western civilizations through its classical formulations and transformation in the Renaissance. Basic strategies, key conceptions, and taxonomic and quantitative approaches.
deSantillana

21.702 *Origins of Modern Scientific Thought*
Prereq.: 21.701
Year: U (2) 3–0–5
Study of the period from the Scientific Revolution and the founding of modern scientific thought to the present. Formation of the main theories and conceptions, their philosophical implications, and the interactions of science and society. (*Not offered 1968–69.*)
deSantillana

21.712 *Philosophy of Science*
Prereq.: One philosophy subject above 21.04
Year: U (2) 3–0–5
Discussion of philosophical problems arising in the natural sciences: inductive inference; perceptual data and reality; common sense and scientific theories; interrelations among the sciences. (*Not offered 1968–69.*)
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21.714T *Philosophy of Mathematics* (A)
Prereq.: ——
Year: G (2) 3–0–9
Examination of major philosophies of mathematics — logicism, formalism, intuitionism — on the nature of mathematical proof, existence of mathematical entities, and related issues. (*For graduate students, and for undergraduates having permission of instructor. It is strongly suggested that students have taken 21.641 or its equivalent.*)
James F. Thomson

21.715 *Philosophy of Physics* (A)
Prereq.: ——
Year: G (1) 3–0–9
Consideration of philosophical problems concerning the foundations of quantum mechanics and statistical mechanics. (*For graduate students, and for undergraduates having permission of instructor. It is strongly suggested that students have taken 8.05 and 8.06 or their equivalents.*) (*Not offered 1968–69.*)
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21.716 *Philosophy of Mind* (A)
Prereq.: ——
Year: G (2) 3–0–9
Some concepts and problems in the philosophy of mind, such as the relations between minds and bodies, sensation and feeling, thinking, and perceiving. (*Primarily for graduate students in philosophy; undergraduates who have taken 21.04 and 21.647 may be admitted by consent of the instructor.*)
Judith J. Thomson

21.721 *Semantics* (A)
Prereq.: ——
Year: G (1) 3–0–9
Characterization of the form of a semantic theory of a natural language. Basic consideration of (1) phenomena falling within the domain of a semantic theory and (2) the descriptive goals of a semantic theory, the kind of theory employed in pursuit of these goals, and the empirical and methodological requirements upon an adequate semantic theory. (*Primarily for graduate students; others admitted only by permission of instructor.*)
Katz

21.724 *Philosophy of Language* (A)
Prereq.: ——
Year: G (2) 3–0–9
Study of recent philosophical movements concerned with the treatment of traditional philosophical problems from a linguistic movement; in particular, logical positivism and ordinary language philosophy. Consideration of the treatment of philosophical problems within the framework of linguistic theory. Some acquaintance with Chomsky's theory of generative grammar desirable. (*Primarily for graduate students in philosophy; undergraduates who have taken 21.04 may be admitted by consent of the instructor.*)
Katz

21.725 ***Seminar: Problems in the Philosophy of Language*** **(A)**
Prereq.: ——
Year: G (2) *Arr.*
Study of various problems in the philosophy of language. (*Primarily intended for graduate students in philosophy and linguistics.*) *Bromberger*

21.781 ***Graduate Seminar*** **(A)**
Prereq.: ——
Year: G (1) *Arr.*
A graduate proseminar in which students will be presenting original work. (*Second- and third-year graduate students in philosophy must attend unless explicitly excused. First-year graduate students in philosophy are invited to participate.*) *Staff*

21.782 ***Graduate Seminar*** **(A)**
Prereq.: ——
Year: G (2) *Arr.*
A graduate proseminar in which students will be presenting original work. (*Second- and third-year graduate students in philosophy must attend unless explicitly excused. First-year graduate students in philosophy are invited to participate*). *Staff*

21.791 ***Special Topics in Philosophy***
Prereq.: Any two subjects in philosophy
Year: U (1) *Arr.*
Open to qualified students who wish to pursue special studies or projects with members of the Philosophy Section. Students electing this subject must consult the Chairman of the Section. *Staff*

21.792 ***Special Topics in Philosophy***
Prereq.: Any two subjects in philosophy
Year: U (2) *Arr.*
Open to qualified students who wish to pursue special studies or projects with members of the Philosophy Section. Students electing this subject must consult the Chairman of the Section. *Staff*

21.793 ***Special Advanced Topics in Philosophy*** **(A)**
Prereq.: ——
Year: G (1) *Arr.*
Open to qualified graduate students in philosophy who wish to pursue special studies or projects with members of the Philosophy Section. *Staff*

21.794 ***Special Advanced Topics in Philosophy*** **(A)**
Prereq.: ——
Year: G (2) *Arr.*
Open to qualified graduate students in philosophy who wish to pursue special studies or projects with members of the Philosophy Section. *Staff*

MUSIC

21.81 ***Materials of Music***
Prereq.: ——
Year: U (1, 2) 3–0–5
Introductory subject in music for students with no formal musical background. Elementary study of musical materials. Exercises in notation, ear training, melodic and harmonic interactions, and their application to the musical literature. Listening to recordings. Written assignments. *Staff*

21.82 ***Introduction to Music***
Prereq.: 21.81
Year: U (1, 2) 3–0–5
Continuation of 21.81. Formal analysis of representative masterworks through lectures, demonstrations and concerts. Extension of theoretical studies of 21.81. Listening to recordings; exercises; readings, written assignments. *Staff*

21.821 ***Music Theory I***
Prereq.: 21.82
Year: U (1, 2) 3–0–5
Study of harmony and counterpoint as developed in the period of tonal music. Readings, weekly exercises and writing assignments, and analysis of the music of this period. (*Permission of instructor required.*) *Staff*

21.822 ***Music Theory II***
Prereq.: 21.821
Year: U (1, 2) 3–0–5
Continuation of the work initiated in Music Theory I. Study and the constructior of larger musical phrases and forms and the harmonic and contrapuntal principles upon which they depend. Readings, weekly exercises and writing assignments, and analysis of music. (*Permission of instructor required.*) *Staff*

21.823 ***Problems and Techniques of Music Research***
Prereq.: 21.822
Year: U (1, 2) 3–0–5
Studies in the structure of music and theories of music, with emphasis upon the use of the computer. Representation of music notation for computer input, appropriate programming languages and data-structures, and the development of relevant models. Readings, papers, discussions, research projects. (*Permission of instructor required.*) (*Not offered 1968–69.*) ——

21.824 ***Musical Form and Analysis***
Prereq.: 21.821
Year: U (2) 3–0–5
Consideration of differing concepts of musical structure and formal organization, viewed in historical perspective. Study of generalized formal models and the unique formal aspects of specific works. Study of scores, listening to recordings and readings. (*Permission of instructor required.*) *D. M. Epstein*

21.825 ***Orchestration***
Prereq.: 21.821
Year: U (1) 3–0–5
An examination of the construction and techniques of orchestral instruments. Graded exercises in instrumentation for strings, woodwinds, brass — separately and subsequently in combination. Deliberate imitative orchestration of selected passages from compositions with the composers' orchestral technique. (*Permission of instructor required.*) *J. Cook*

21.83 ***Western Music in the Middle Ages and the Renaissance***
Prereq.: 21.82
Year: U (1) 3–0–5
Study of representative composers in their historic perspective with emphasis on outstanding examples of masterworks of the Middle Ages and the Renaissance. Listening to recordings, weekly exercises, and readings required. (*Not offered 1968–69.*) ——

21.84 ***Western Music in the Baroque Era***
Prereq.: 21.82
Year: U (2) 3–0–5
Study of representative composers in their historic perspective, with emphasis on outstanding examples of masterpieces of the Baroque era. Listening to recordings, weekly exercises, and readings required.
R. S. Freeman

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21.85 ***Western Music in the Classic Era***
Prereq.: 21.82
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*

21.86 ***Western Music in the Romantic Era***
Prereq.: 21.82
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.
R. S. Freeman

21.871 ***Twentieth-Century Music***
Prereq.: 21.82
Year: U (1) 3–0–5
Study of principal works by masters of the twentieth century. Tradition and innovation as exemplified in the music of Stravinsky, Bartok, Hindemith, Copland, Ives, Prokofieff, and other composers. The interrelationship of art music, folk music, and popular music. Concerts, recordings, and discussion. (*Permission of instructor required.*) *Tucker*

21.872 ***Twentieth-Century Music: Schoenberg, Berg and Webern***
Prereq.: 21.82
Year: U (2) 3–0–5
Study of the principal works of Schoenberg, Berg and Webern, and of other dodecaphonic compositions. Concerts of representative solo and chamber music. Study of electronic and other experimental music. (*Permission of instructor required.*) *Tucker*

21.88 ***The Opera***
Prereq.: 21.82
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. As far as possible, special attention given to current productions of opera in the Boston area. *J. Cook*

21.891 ***Seminar in Music***
Prereq.: 21.82
Year: U(1) 3–0–5
Varying topics from year to year. Topic for fall 1968: A Collegium Musicum on Bach's orchestral works. A thorough study of these works through analysis, comparison with similar works, and playing. Careful rehearsal, not for the sake of performance, but in order to further the most thorough knowledge of the music. Reading, discussions, papers. (*Permission of instructor required.*) *Liepmann*

21.892 ***Seminar in Music***
Prereq.: 21.82
Year: U (2) 3–0–5
Varying topics from year to year. Topic for spring 1969: A Collegium Musicum on the String Quartets of Mozart. A thorough study of the music through analysis, comparison with similar works, and playing. Careful rehearsal, not for the sake of performance, but in order to further the most thorough knowledge of the music. (*Limited to string players. Permission of instructor required. Not offered 1968–69.*) *Liepmann*

SPECIAL INTERDISCIPLINARY SUBJECTS

21.95 ***Poetic and Scientific Discourse in Classical Literature***
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Myth and logic as differential languages for, and perspectives upon, reality. Special emphasis on the transition from one to the other. Readings in Solon, Pindar, Simonides; in philosophical poets like Parmenides, Empedocles, Lucretius; and in Plato and Aristotle on the truth-value of art. (*Not offered 1968–69.*) *Reiche*

21.951 ***Introduction to the Far East***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Interdisciplinary approach to the classical civilizations of China and her immediate neighbors — especially Japan — from earliest times until the mid-nineteenth century. Emphasis on style in art, literature, and science as well as on political and social development. Recommended, but not required, preparation for other subjects concerned with the Far East. *Sivin, Watt*

21.96 ***Problems in Contemporary Philosophy and Theology: The Problem of God***
Prereq.: 21.04
Year: U (2) 3–0–5
An attempt to bring into sharp juxtaposition and relation the most recent thought of contemporary theologians and philosophers concerning problems of the concept of God, the knowledge of God, language about God, and the existence of God. A careful study of the relevant writings of two or three leading theologians (Barth, Niebuhr, Tillich) followed by an examination of their views in terms of the critical analysis of selected British and American philosophers. Some attention given the current "death of God" theologians. *W. R. Crout*

21.964 ***Religion and Society in America***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Examination of some historical episodes in which religion shaped and was shaped by social conditions and processes: voluntary religion and the democratic state; exodus and utopia; wilderness and paradise themes; the frontier and revivalism; denominationalism and slavery; evangelism and industrialization; "God is dead" theology and secularization. (*Not offered 1968–69.*) *Wertz*

21.965 ***Seminar on Boston***
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Use of historical and contemporary Boston as a laboratory for the study of social change. By means of field trips, visual material, guest lecturers and historical analysis, examination of the dynamics of the city: the social bases of aspiration, conflict and compromise; plans for reordering the physical space of the city; economic and technological influences. Attention to three periods: the founding of Puritan Boston, Yankee-Irish Boston, and the present which will focus on the Boston Redevelopment Authority's plans, the Black Power movement and the attitudes of "suburbia" toward the city. *Wertz*

21.97 ***Biological Bases of Perception and Knowledge***
Prereq.: One first-year Hum. sequence
Year: U (1) 3–0–5
Inquiry into assumptions underlying physiological and psychological experiments in perception as these reraise the question of whether the study of brain function can avoid metaphysical commitment. The mind-body problem in contemporary guise. *deSantillana, Lettvin*

21.98 ***History of Atomic Theory***
Prereq.: 8.04, 21.012
Year: U (2) 3–0–5
History of the development and use of atomic and corpuscular theories from the ancient Greeks to about 1900. Greek theories of the constitution and interactions of matter: the pre-socratic philosophers, Plato, Aristotle and his commentators, Epicurus and Lucretius. The opposition to atomism. Survival of atomism in the

Middle Ages, and the Renaissance; the theory of natural minima. Moslem and Indian atomism. The revival of atomic theory in the seventeenth century; atomism and the mechanical philosophy: Sennert, Gassendi, Boyle, Newton. Dalton's atomic theory. Chemical and physical atomic theories of the nineteenth century. The struggle against atoms and the final triumph of atomic theory. Background of the Bohr theory. *Kaplan*

21.99 *E. M. Forster*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Seminar on the author's published works. (*Limited to ten students.*) *Zacharias*

21.991 *Utopian Literature*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Study of the imagination of utopia in literature and political thought since the Renaissance: the transformation of utopia from a literary invention, specifically rooted in the Renaissance imagination of pagan antiquity, into the nineteenth-century idea of a set of historically realizable goals; consideration of the twentieth-century vision of utopia as a final political condition from which all possibilities of freedom have been evacuated: the so-called anti-utopia. Readings of works by More, Rabelais, Swift, Stendhal, Samuel Butler, Dostoevsky, Zamiatin, D. H. Lawrence, and selections from Rousseau, Fourier, St. Simon, Engels, Marx, as well as samples of current utopian speculation. (*Limited to 25 students.*) *Goodheart, Kibel*

21.992 *Tradition and Innovation in Twentieth-Century Physics*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Evolution of the new ideas of twentieth-century physics, especially in relativity and quantum mechanics. Value of such notions as paradigm, model, and ideal of natural order in understanding the dynamics of scientific growth and revolutions. Relative importance of individual genius, tradition, and formal methodological rules. Interactions of physics with the philosophy of science. Features unique to the twentieth century. *Graves*

21.993T *Film and the Anthropological Imagination*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
Examination of social organization, technology and symbolic systems in pre-literate cultures through the medium of film. Study of films both as a source of anthropological data or evidence and as a reflection of hypotheses about reality in the thinking of both social scientists and artists. Research films, ethnographic films and films portraying contemporary cultures from various countries. (*Limited enrollment.*) *Guggenheim*

21.995 *Intellectuals and Social Change*
Prereq.: One first-year Hum. sequence
Year: U (2) 3–0–5
The role and responsibility of individuals who challenge the assumptions of the established political and social order, and who are concerned with ideas and their consequences. Discussion of current issues that have given rise to action and protest, in particular: American foreign policy, the problem of poverty, the Negro revolution, the role of university students. Questions of individual commitment, and the available alternatives for action. Historical background, with emphasis on socialist, anarchist, and liberal responses to recurrent problems which have faced the committed individual since the Enlightenment and Industrial Revolution. Study of the conditioning of these responses by the relation of intellectuals to established institutions such as government and the universities. Individual research on topics of particular current significance. (*Limited to 25 students.*) *Chomsky, Kampf*

21.996 *American Values of the 1920's*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Mencken and *The American Mercury*, Ross and *The New Yorker*. Creative activity in Greenwich Village and Harlem. Work of expatriates — Fitzgerald, Hemingway. The image of America in *Colliers* and *The Saturday Evening Post*. Consideration of some "best sellers." *T. Wood*

21.997 *The Concept of Freedom in Modern Literature*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (2) 3–0–5
Case study in the literature of ideas, exploring not only the various definitions of freedom — political, social, spiritual, sexual — in modern thought but also the special problems and advantages of literature as a form of argument. Readings include some modern novelists, J. S. Mill, Marx, Freud, and other literary, philosophical and political texts. (*Limited enrollment.*) *Hawley*

21.998T *Literature and Communication*
Prereq.: 21.03 or 21.031 or 21.11
Year: U (1) 3–0–5
Study of the effects of major cultural shifts on literature which examines the development of various modes of literary communication from the oral tradition to the modern period. *Zingrone*

21.999 *Analysis and Synthesis of Musical Sounds*
Prereq.: 21.82
Year: U (1, 2) 1–2–5
Recording of sounds, wave form analysis, and an evaluation of listening to musical sounds. Analysis by sound synthesis with the use of the computer. Lectures, laboratory projects and weekly assignments in sound synthesis. (*Not offered in 1968–69.*) ——

22.
Nuclear Engineering

22.01 *Introduction to Nuclear Reactor Engineering*
Prereq.: 8.01, 18.02
Year: U (1) 3–0–9
Introduction to the basic scientific and engineering principles underlying the production of useful energy from nuclear fission. Neutron diffusion in, and interaction with, materials. Characteristics of the fission process and their influence upon the reactor physics and engineering design of an integrated nuclear power plant. *Driscoll*

22.10 *Elementary Nuclear Physics*
Prereq.: 8.03T, 18.034
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. *Rasmussen*

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22.20 ***Biological Effects of Nuclear Radiation*** **(A)**
Prereq.: 8.272 or 22.10
Year: G (1) 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. (*Not offered 1968–69.*) *Brownell*

22.21 ***Nuclear Reactor Physics I*** **(A)**
Prereq.: 8.272 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. *Gyftopoulos, Chen*

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. *Clikeman*

22.231 ***Nuclear Reactor Engineering*** **(A)**
Prereq.: 2.50, *22.21*
Year: G (1) 3–0–9
Engineering principles of nuclear reactors with emphasis on applications in central station power reactors. Power plant thermodynamics; energy production and distribution; heat transfer by conduction, convection by incompressible fluids, boiling; thermal stress analysis; reactor types. *Fenech*

22.232 ***Nuclear Engineering for Space Applications*** **(A)**
Prereq.: 22.231
Year: G (2) 3–0–9
Continuation of nuclear engineering principles with emphasis on applications in space nuclear power sources. Nuclear rocket and auxiliary space power systems; flow and heat transfer of compressible gases; radiant heat transfer; thermoelectric and thermionic energy conversion; shielding; design and optimization of reactor systems. *Fenech*

22.241 ***Principles of Control Systems*** **(A)**
Prereq.: 8.03T, 18.034
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 non-linear problems. (*Alternate years. Not offered 1968–69.*) *Gyftopoulos*

22.242 ***Nuclear Plant Dynamics*** **(A)**
Prereq.: 6.213T 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 non-linear nuclear plant dynamics, development of boundedness a .d stability criteria for non-linear systems. Synthesis of control systems. (*Alternate years. Not offered 1968–69.*) *Gyftopoulos*

22.243 ***Space-Time Reactor Kinetics*** **(A)**
Prereq.: 22.22
Year: G (2) 3–0–9
Development of methods for predicting dynamic behavior when space and time are not separable. Application of the point kinetics formalism, the adiabatic method, direct finite space-time difference approach; nodal methods and the application of orthogonal and non-orthogonal modes; flux synthesis schemes based on variational and weighted residual techniques. *Henry*

22.25 ***Advanced Reactor Physics*** **(A)**
Prereq.: 22.22
Year: G (1) 3–0–9
Review of current methods for predicting neutron behavior in complex geometrical and material configurations. Systematic few-group procedures; blackness theory for control rods; the S_n method; cell theory; flux synthesis techniques; the use of variational and weighted residual techniques to derive approximation methods in a systematic manner. *Henry*

22.26 ***Nuclear Reactor Design*** **(A)**
Prereq.: 22.22 or 22.242; 22.231
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. *Driscoll*

22.27 ***Economics of Nuclear Power*** **(A)**
Prereq.: 22.21, 22.231
Year: G (2) 2–0–6
Projected growth of nuclear power; fuel cycle performance of typical reactors; reactor uranium requirements; uranium resources and costs; fuel cycle costs; nuclear plant costs; power cost accounting; interrelation between costs of nuclear power and conventional power. *E. A. Mason*

22.28 ***Fast Power Reactors*** **(A)**
Prereq.: 22.21, 22.231
Year: G (1) 2–0–6
Reactor engineering and physics of fast reactors. Current status; design and operational problems; safety considerations; future large fast breeder reactors; economics. (*Alternate years.*) *T. J. Thompson*

22.29 ***Thermal Power Reactors*** **(A)**
Prereq.: 22.21, 22.231
Year: G (1) 2–0–6
A survey of the reactor engineering and reactor physics aspects of large nuclear power reactors operating principally by thermal neutron fission. Current status; design and operational problems; safety considerations; future plant designs. Students will conduct a competitive survey of several promising designs. (*Alternate years. Not offered 1968–69.*) *T. J. Thompson*

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. (*Alternate years.*) *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. *Clikeman, Olson*

22.42T ***Nuclear Reactor Operations*** **(A)**
Prereq.: 22.21, 22.41
Year: G (2) 2–6–4
Techniques of nuclear reactor operation, initial fuel loading, criticality considerations, startup reactivity effect measurements, measurements at power; operating experience at power reactor facilities including hazards evaluation and accident experience; group and individual participation in startup and operations at the M.I.T. Nuclear Reactor, investigation of M.I.T. Reactor operational problems. *T. J. Thompson*

22.44 ***Basic Electronic Instrumentation Laboratory***
Prereq.: ——
Years: G (S) 1–2–5
For engineering research students with little or no background in electronics, who need a working knowledge of electronic devices and circuits. Basic laws and electronic principles, basic circuits and components, servo systems, operational amplifiers, feedback control, digital circuits and logic and other devices, using both tube and transistor circuitry. (*Alternate years. Not offered 1968–69.*) *Clikeman*

22.51 ***Neutral Particle Transport*** **(A)**
Prereq.: 8.341T; or 18.15 and 22.21; or 18.28
Year: G (2) 3–0–9
Boltzmann and integral transport equations. Infinite space and Milne problems. Spherical harmonic and variational methods. Corrections to diffusion theory. Slowing down theory. Special methods of solving transport equations. Adjoint functions. *K. F. Hansen*

22.53 ***Numerical Methods of Reactor Analysis*** **(A)**
Prereq.: 22.21
Year: G (1) 4–0–8
Applications of digital computers to nuclear engineering problems. Programming of digital computers. Matrix algebra, difference equations, numerical solution of equations. Special topics such as multigroup methods, S_n methods, Monte Carlo methods, and Spencer-Fano method. *Yip*

22.531 ***Digital Computers in Nuclear Engineering*** **(A)**
Prereq.: 22.21
Year: G (1) 1–0–2
Programming aspects of 22.53. *W. H. Reed*

22.54 ***Radiation Shielding*** **(A)**
Prereq.: 8.272 or 8.722T or 22.10; 22.21
Year: G (1) 3–0–6
Shielding of nuclear reactors, accelerators and space vehicles. Interaction of γ-rays, neutrons and charged particles with matter. Energy range from thermal through cosmic rays. Application of particle transport theory to penetration of shields. (*Alternate years.*) *K. F. Hansen*

22.55 ***Neutron Physics and Applications*** **(A)**
Prereq.: 8.721T
Year: G (2) 3–0–6
Basic principles of neutron interaction with nuclei in matter. Applications to cross section calculation for reactor design and to scattering experiments for the study of material properties. Fast neutron cross sections, resonance absorption, neutron thermalization, general properties of inelastic scattering of thermal and cold neutrons in liquids and solids, and analysis of current experiments. *Yip*

22.61 ***Plasmas and Controlled Fusion*** **(A)**
Prereq.: 8.04; 8.06 or 8.272 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. *D. J. Rose*

22.62 ***Advanced Plasma Principles*** **(A)**
Prereq.: 8.261 or 22.61; 8.311T
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; recent experiments. *D. J. Rose*

22.63 ***Engineering Physics of Plasma and Particle Devices*** **(A)**
Prereq.: 6.03 or *22.61*
Year: G (1) 3–0–6
Principles of accelerators and thermonuclear research devices, including vacuum systems, magnets, acceleration methods, ion sources, targets, lasers, and laser diagnostics. Examples from recent practice. *Lidsky*

22.65 ***Plasma Laboratory*** **(A)**
Prereq.: 2.274 or *8.261* or *22.61* or *22.63*
Year: G (2) 1–4–4
Introduction to the advanced experimental techniques needed for research in plasma physics and useful in experimental atomic and nuclear physics. Laboratory work on vacuum systems, plasma generation and diagnostics, physics of ionized gases, ion sources and beam optics, cryogenics, magnetic field generation, and other topics of current interest; brief lectures and literature references to elucidate the physical bases of the laboratory work. *Lidsky*

(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.

22.68J ***Plasma Kinetic Theory*** **(A)**
(Same subject as 8.621J)
Prereq.: 8.611 or 8.622 or 16.59
Year: G (1) 3–0–9
Content varying from year to year. Typical subjects: the linearized Vlasov equation, Fokker-Planck and diffusion approximations for the average distribution function, autocorrelation functions, resonant and non-resonant diffusion, free energy, energy and momentum conservation, resonant wave coupling, non-linear Landau damping, strong turbulence theories. Selected applications to enhanced diffusion, stochastic acceleration, turbulent resistivity, shock waves, radio emission. *Dupree*

22.69J ***Advanced Topics in Plasma Kinetic Theory*** **(A)**
(Same subject as 16.581J)
Prereq.: 22.68J
Year: G (2) 3–0–9
Varying content including topics of current interest. Typical subjects: theories of non-linear phenomena in plasma, particularly in the regime described by the Vlasov equation. General normal mode analysis, Van Kampen modes, radiation, limitations of the linear theory, resonance and trapping, continuum modes. Multiple length-and-time-scale formulations. Non-linear stationary wave solutions, shock waves. Unstable plasmas, phase space and statistical considerations, entropy. Computer experiments. Perturbation methods, quasi-linear theory, mode coupling. N-momentum space description, master equation, general H-theorem, equilibrium. *Dupree, McCune*

22.71 ***Metallurgy for Nuclear Engineers*** **(A)**
Prereq.: ——
Year: G (2) 3–0–9
Crystallography and microstructure of engineering materials. Elastic and plastic properties of metals and relation of mechanical properties to metallurgical structure. Phase relations in metals; phase transformations and diffusion kinetics. Corrosion and oxidation. Effects of radiation on mechanical properties. Emphasis throughout is on materials used in nuclear reactor systems — structural alloys, fuels, moderators, and control materials. *Ziebold*

22.72J ***Nuclear Fuels*** **(A)**
(Same subject as 3.72J)
Prereq.: 3.13 or 3.14 or 22.71
Year: G (1) 2–0–6
Behavior of nuclear fuels and fuel element cladding materials in reactor cores. Experimental observations and theory of radiation damage to metals and ceramics of practical interest. Processes for fabricating fuel elements and fuel assemblies; fuel fabrication costs. Recent developments of advanced reactor core materials. (*Alternate years. Not offered 1968–69.*) *Ziebold*

22.721J ***Radiation Damage in Crystalline Solids*** **(A)**
(Same subject as 3.721J)
Prereq.: 3.13 or 3.14 or 22.71
Year: G (1) 2–0–6
Theory of atomic displacements, cascades, and spike phenomena produced in metals and ceramics by high energy radiation bombardment. Recovery of damage related to mobility and structure of crystalline imperfections. Discussion of radiation damage experiments of technological importance and basic experiments designed to test the theory of damage production and recovery. Consideration of special problems associated with damage in fissionable materials. Brief outline of the role of materials in nuclear reactor design. (*Alternate years.*) *Ziebold*

22.81 ***Radiation and Radioisotope Applications*** **(A)**
Prereq.: 8.272 or 22.10
Year: G (2) 3–0–6
Basic topics include production of radiation and radioisotopes, interaction of radiation with matter, detection, dosimetry, radiation chemistry and biology. Various topics such as radiation preservation and synthesis, radiation modification of materials, radiation gauging, and use of radioisotopes as terrestial and space power sources explored in depth. Emphasis on student participation. *Brownell*

22.90 ***Special Problems in Nuclear Engineering*** **(A)**
Prereq.: —
Year: G (1, 2) *Arr.*
For graduate and advanced undergraduate students who wish to carry out a one-term project of a theoretical or experimental nature in the nuclear engineering field in close cooperation with individual staff members. Arrangement of topic and hours to fit student requirements. *Driscoll*

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. *Rasmussen*

23.
Modern Languages and Linguistics

23.011 ***The Greek Tradition***
Prereq.: ——
Year: U (1) 3–0–6
Study of the foundations of Western civilization through selected masterworks of Greek literature (*The Iliad, The Oresteia*), history (*The Peloponnesian War*), and philosophy (*The Apology, Phaedo, The Republic*). Readings and lectures in French. Discussion in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

23.021 ***The Judaeo-Christian Tradition***
Prereq.: 23.011
Year: U (2) 3–0–6
Study of the foundations of Western civilization through selected works of the Old and New Testaments: e.g., Genesis, Job, various of the historical and prophetic books, the Gospels, and various epistles. Readings, lectures, and discussion in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) *Bottiglia*

23.022 ***The European Tradition: Goethe Era***
Prereq.: 21.011
Year: U (2) 3–0–6
Introduction to literature and thought in the era of Goethe. Reading and discussion of works by Lessing, Goethe, Schiller, Novalis, Tieck, Eichendorff, and Kleist. The major movements of the period: Aufklärung, Sturm und Drang, Klassik, Romantik. Some attention to such thinkers as Kant and Fichte. Instruction in German. Discussion in German and English. Papers, exercises and examination in English. (*Restricted to students with an adequate background in German.*) *Dyck*

23.031 ***The Nature of Literature***
Prereq.: 23.051T
Year: U (2) 3–0–6
Training in background, internal and comparative analysis of modern poems (by Eliot, Yeats, St. John Perse), plays (by Giraudoux, Sartre, O'Neill), and novels (by Camus, Malraux, Faulkner). Readings in French and English. Lectures and discussion in French. Tests and essays in English. (*Restricted to students with adequate background in French.*) *R. E. Jones*

23.032 ***The Nature of Literature***
Prereq.: 23.022
Year: U (1) 3–0–6
Introduction to the analysis of poetry, drama, and fiction. An examination of the various strata, and of their interrelations, in the total experience of reading a literary work. Structure, sound, style; idea, meaning, substance; the metaphoric spectrum. Examples drawn chiefly from modern German poetry (George, Rilke, Hofmannsthal, and others), drama (Hauptmann, Brecht, Dürrenmatt, and others), and fiction (Thomas Mann, Kafka, and others). Instruction in German. Discussion in German and English. Papers, exercises and examination in English. (*Restricted to students with an adequate background in German.*) *Dyck*

23.051T ***The French Enlightenment***
Prereq.: 23.021
Year: U (1) 3–0–6
Training in the elements of historical method through analysis of major developments in the French Enlightenment. Focus on political, economic and social phenomena. Some attention to cultural manifestations as well. Readings in primary sources and works of interpretation. Lectures, discussion, and readings in French. Tests and essays in English. (*Restricted to students with an adequate background in French.*) *R. E. Jones*

23.052 ***The Twentieth Century: Revolution, War, and "Totalism"***
Prereq.: 23.032
Year: U (2) 3–0–6
Training in the elements of historical method through analysis of some major developments in today's world. Focus on political, economic, and social phenomena, with special attention to Germany. Readings in primary sources and works of interpretation. Readings and lectures in German. Discussion and tests in German and English. Essays in English. (*Restricted to students with an adequate background in German.*) *Dyck*

23.11 ***Elementary German***
Prereq.: ——
Year: U (1, 2) 4–0–8
Basic principles of the German language. Fundamentals of pronunciation, intonation, and grammar. Acquisition of basic vocabulary. Laboratory exercises to further comprehension and oral expression. Reading of simple texts, practice in writing. *Bon*

23.12 ***Elementary German***
Prereq.: 23.11
Year: U (1, 2) 4–0–8
Continued practice in pronunciation and intonation. Extension of vocabulary for both conversational and literary purposes. Review and extension of basic grammar. Practice in writing short essays. Introduction to the history and culture of German-speaking countries. Conducted partly in German. *Bon*

23.13 ***Intermediate German***
Prereq.: 23.12
Year: U (1, 2) 4–0–8
Intensive review of general linguistic forms and idiomatic structures, with emphasis on literary usage. Readings designed to broaden acquaintance with German thought and culture. Class discussion and essays on the reading material. Conducted in German. *Bon*

23.14 ***Advanced German***
Prereq.: 23.13
Year: U (1, 2) 4–0–8
Extensive practice in reading, writing, and speaking German. Readings in narrative prose, drama, and poetry as an introduction to German literature and in relation to historical and cultural developments. Oral and written analyses of texts. Conducted in German. *Bon*

23.15 ***Goethe's Poetry***
Prereq.: 23.14
Year: U (1) 3–0–5
An intensive analysis of representative poems from Goethe's entire career. Supplementary readings in Goethe's thought. Instruction in German. Discussion and papers in English or German. (*Not offered 1968–69.*) *Dyck*

23.16 ***German Romanticism***
Prereq.: 23.14
Year: U (2) 3–0–5
A critical study of literary works of the German Romantic movement, with emphasis on Novalis, Friedrich Schlegel, Tieck, Brentano, Eichendorff, and Hoffmann. Some attention to the manifestations of Romanticism in extraliterary domains: music and painting, science and religion, philosophy and political thought. Instruction in German. Discussion and papers in English or German. (*Not offered 1968–69.*) *Dyck*

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*

23.171 ***Intensive German I***
Prereq.: ——
Year: G (1) 4–0–8
Introduction to speaking and understanding German. No previous knowledge of German required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. *Staff*

23.172 ***Intensive German II***
Prereq.: 23.171
Year: G (2) 4–0–8
Continued training in speaking and understanding German. Increased practice in reading. Continued use of language laboratory. *Staff*

23.19 ***Goethe's "Faust"***
Prereq.: 23.14
Year: U (1) 3–0–5
An intensive analysis of both parts of *Faust*. Instruction in German. Discussion and papers in English or German. (*Not offered 1968–69.*) *Dyck*

(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.

23.20 ***Seminar in German Poetry***
Prereq.: 23.14
Year: U (2) 3–0–5
Introduction to various methods of analysis, intrinsic and extrinsic, and to the major phases of German poetry, through detailed analysis of some two dozen representative poems written since 1600. Followed by concentration on one poet, e.g., Hölderlin, Schiller, Brentano, Eichendorff, Heine, Mörike, Droste-Hülshoff, C. F. Meyer, George, Rilke, Hofmannsthal, Trakl, Heym, Benn, or a more recent one. Instruction in German. Discussion and papers in English or German. (*Limited enrollment.*) *Dyck*

23.21 ***Modern German Drama***
Prereq.: 23.14
Year: U (1) 3–0–5
An intensive analysis of representative German plays written since 1880. The evolution of themes and techniques from naturalism and expressionism to more recent times. Major authors: Hauptmann, Hofmannsthal, Kaiser, Brecht, Frisch, Dürrenmatt. Instruction in German. Discussion and papers in English or German. *Dyck*

23.22 ***Modern German Fiction***
Prereq.: 23.14
Year: U (2) 3–0–5
Critical reading and discussion of examples of modern German prose fiction, with emphasis on Mann and Kafka. Instruction in German. Discussion and papers in English or German. (*Not offered 1968–69.*) *Dyck*

23.24* ***The Modern German Novel***
Prereq.: 21.03 or 21.031 or 21.11 or 23.031 or 23.032
Year: U (2) 3–0–5
Close study of novels by such writers as Raabe, Mann, Döblin, Kafka, Jünger, Broch, Musil, Böll, and Grass. Readings in translation. Conducted in English. (*Not offered 1968–69.*) *Dyck*

23.26* ***Modern German Drama***
Prereq.: 21.03 or 21.031 or 21.11 or 23.031 or 23.032
Year: U (2) 3–0–5
Close study of plays by Lessing, Kleist, Büchner, Hebbel, Wedekind, Schnitzler, Brecht, Frisch, Dürrenmatt, and others. Readings in translation. Conducted in English. (*Not offered 1968–69.*) *Dyck*

23.35 ***Spanish Drama***
Prereq.: 23.41
Year: U (1) 3–0–5
Reading and discussion of works by Lope de Vega, Cervantes, Tirso de Molina, Ruiz de Alarcón, Calderón de la Barca, Rojas Zorilla, Moratín, Duque de Rivas. Conducted in Spanish. (*Limited enrollment. Not offered 1968–69.*) *J. W. Harris*

23.36 ***Twentieth-Century Spanish Literature***
Prereq.: 23.41
Year: U (2) 3–0–5
Study of philosophical works by Unamuno, Ortega y Gasset. Reading and discussion of literary prose works by Azorín, Pío Baroja, Valle-Inclan, and others. Conducted in Spanish. (*Limited enrollment. Not offered 1968–69.*) *J. W. Harris*

23.371 ***Intensive Spanish I***
Prereq.: ——
Year: G (1) 4–0–8
Introduction to speaking and understanding Spanish. No previous knowledge of Spanish required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. *J. W. Harris*

23.372 ***Intensive Spanish II***
Prereq.: 23.371
Year: G (2) 4–0–8
Continued training in speaking and understanding Spanish. Increased practice in reading. Continued use of language laboratory. *J. W. Harris*

23.41 ***Introduction to Spanish Literature***
Prereq.: ——
Year: U (1) 3–0–5
Detailed study of poems, plays, and prose works by such writers as Arreola, Baroja, Casona, Guzmán, and Neruda. Emphasis on control of grammar and rapid acquisition of vocabulary, leading to the ability to read standard works with immediate comprehension and pleasure. Conducted largely in Spanish. *J. W. Harris*

23.42 ***Masterpieces of Spanish Literature***
Prereq.: 23.41
Year: U (2) 3–0–5
Careful study of unabridged works of recognized masters in various genres, largely contemporary and largely Latin American, such as Arciniegas, Borges, García Lorca, Mistral, Romero, and Paz. Conducted in Spanish. *J. W. Harris*

23.51 ***Elementary French***
Prereq.: ——
Year: U (1, 2) 4–0–8
Necessary foundation for French language and literature. Training in pronunciation and intonation with the aid of mechanical devices, and in elementary grammar; practice in hearing and speaking French; acquisition of useful vocabulary; reading of varied matter. *Greenfield*

23.52 ***Elementary French***
Prereq.: 23.51
Year: U (1, 2) 4–0–8
Continued training in the speaking and listening skills with the aid of mechanical devices. Completion of elementary grammar. Practice in reading to increase vocabulary and to develop some appreciation of French literature and civilization. *Kramsch*

23.53 ***Intermediate French***
Prereq.: 23.52
Year: U (1, 2) 4–0–8
Practice in spoken French to develop fluency in everyday conversation; also in written French to increase accuracy. Grammar review; reading of varied matter. Mechanical devices used for improving pronunciation and intonation. Appropriate for Fulbright candidates. *Ricardo*

23.54 ***Conversational French***
Prereq.: 23.53
Year: U (1, 2) 4–0–8
Practice in spoken French to develop fluency in cultural conversation; also in written French to increase accuracy. Reading of varied matter. Appropriate for Fulbright candidates. *Ricardo*

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*

*Readings in English, conducted in English.

23.571 *Intensive French I*
Prereq.: ——
Year: G (1) 4–0–8
Introduction to speaking and understanding French. No previous knowledge of French required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. *Staff*

23.572 *Intensive French II*
Prereq.: 23.571
Year: G (2) 4–0–8
Continued training in speaking and understanding French. Increased practice in reading. Continued use of language laboratory. *Staff*

23.61T *Contemporary French Drama*
Prereq.: 23.54
Year: U (1) 3–0–5
Study of major authors and movements in French drama since 1920: Lenormand, Giraudoux, Anouilh, Montherlant, Claudel, Artaud, Ionesco, Beckett, Genet, Surrealism, Existentialism, etc. Conducted in French.
R. E. Jones

23.62T *French Romanticism*
Prereq.: 23.54
Year: U (2) 3–0–5
Inclusive study of French literature from 1800 to 1860, with emphasis on the poetry of Hugo, Vigny, Musset, Lamartine, Nerval, and Gautier, the novels of Stendhal and Balzac, and the Romantic theatre. Also, examination of the allied arts of music and painting. Conducted in French. *R. E. Jones*

23.63 *French Prose Fiction*
Prereq.: 23.54
Year: U (1) 3–0–5
Analysis of various types and techniques of fiction. Readings selected from several periods of French literature, but emphasis on such nineteenth and twentieth century authors as Flaubert, Zola, Proust, Gide, Malraux, Camus, Bernanos, Céline, and Robbe-Grillet. Conducted in French. (*Not offered 1968–69.*) *R. E. Jones*

23.64 *Seminar in French Literature*
Prereq.: 23.54
Year: U (2) 3–0–5
Detailed study of some aspect of modern French literature. Conducted in French. (*Not offered 1968–69.*)
R. E. Jones

23.65 *Classical French Drama*
Prereq.: 23.54
Year: U (1) 3–0–5
Concentrated study of selected plays by Corneille, Racine, and Molière, and of Boileau's *Art poétique*. Conducted in French. (*Not offered 1968–69.*) *R. E. Jones*

23.66 *Modern French Poetry*
Prereq.: 23.54
Year: U (2) 3–0–5
Detailed analyses of poetry by Nerval, Baudelaire, Rimbaud, Mallarmé, Apollinaire, and the Surrealists. Special attention to the prose poem. Conducted in French. (*Not offered 1968–69.*) *R. E. Jones*

23.701 *Crucial Problems in Linguistics*
Prereq.: ——
Year: G (1) 2–0–7
The Moscow school — Fortunatov, Trubetzkoy, further stages — and its place in world linguistics. (*Not offered 1968–69.*) *Jakobson*

23.702 *Seminar in Language Acquisition*
Prereq.: ——
Year: G (1) *Arr.*
Discussion of the theoretical and factual basis for a model of language learning. Treatment of philosophical, psychological, and linguistic issues concerning language learning as well as the recent evidence from studies on children's language skills. (*Not offered 1968–69.*)
Staff

23.703T *Linguistics and Poetics*
Prereq.: ——
Year: G (1) 2–0–7
Poetic function of language; linguistic analysis of poems; verse, rime, parallelism; phonemic, morphologic and syntactic texture; tropes and figures. *Jakobson*

23.705 *Seminar on Poetic Form*
Prereq.: ——
Year: G (1) *Arr.*
Study of the organization of linguistic elements in metrical verse. (*Not offered 1968–69.*) *Halle*

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 I* (A)
Prereq.: 23.751
Year: G (2) 3–0–9
Introduction to the grammatical devices of English. The interrelation of syntactic, morphological and phonological phenomena in the English language. The phonological system and the structure of phonemes. Special reference to current interpretations by leading structuralists. (*Not offered 1968–69.*) *Kiparsky, J. R. Ross*

23.732 *Structure of English II: Advanced Syntax* (A)
Prereq.: 23.751
Year: G (1) 3–0–9
Selected topics in the syntax of English. (*Not offered 1968–69.*) *J. R. Ross*

23.733T *History of the English Language*
Prereq.: ——
Year: G (1) 3–0–9
Selected topics in the history of English syntax, morphology and phonology from Old English to the present, formulated within an attempt at a general theory of linguistic change. Some knowledge of Old and Middle English desirable. *O'Neill*

23.734 *Structure of Russian* (A)
Prereq.: 23.731, 23.762
Year: G (2) 2–0–10
Survey of the syntax, morphology and phonology of contemporary literary Russian, with emphasis on the application of modern theory to classical problems of Slavic linguistics. Consideration of the relevant dialectological and historical evidence. (*Adequate knowledge of Russian required.*) *Halle*

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23.736 *Structure of German* (A)
Prereq.: 23.731, 23.762
Year: G (2) 2–0–10
Survey of the syntax, morphology and phonology of contemporary literary German, with emphasis on the application of modern theory to classical problems of Germanic linguistics. Consideration of the relevant historical evidence. (*Adequate knowledge of German required. Not offered 1968–69.*) *Kiparsky, J. R. Ross*

23.737 *Introduction to Sanskrit*
Prereq.: ——
Year: G (1) *Arr.*
Brief review of writing system, phonology, morphology, and syntax of the language. (*Not offered 1968–69.*) *Staff*

23.738 *Seminar on English Syntax* (A)
Prereq.: 23.732
Year: G (2) 3–0–9
Continuation of 23.732. *J. R. Ross*

23.74 *Structure of Spanish* (A)
Prereq.: 23.731, 23.762
Year: G (2) 3–0–9
Survey of the syntax, morphology and phonology of contemporary literary Spanish, with emphasis on the application of modern theory to classical problems of Spanish linguistics. (*Adequate knowledge of Spanish required.*) *Hale, J. W. Harris*

23.751 *Introduction to Linguistics I: Syntax*
Prereq.: ——
Year: G (1) *Arr.*
Deep and surface structure. Phrase structure and transformational rules. Recursive mechanisms: relative clauses, complements, conjunctions. Types of ordering. Exception mechanisms and pruning. Universality of deep structure. *Halle, J. R. Ross*

23.752 *Linguistic Structure*
Prereq.: 23.751
Year: G (1) *Arr.*
The empirical requirements for a theory of linguistic structure that will encompass and account for linguistic competence and the ability to use and acquire it. Study of aspects of English syntax, semantics, and phonology insofar as they furnish critical tests for such a theory. Systematic presentation of a theory of linguistic structure, its abstract properties and range of empirical adequacy. Explanatory models in linguistics; their implications concerning the nature of cognitive processes. *Chomsky*

23.754 *Field Methods*
Prereq.: 23.751
Year: G (2) 2–0–7
Survey of means for eliciting linguistically relevant data about a language from a native speaker; for obtaining correct phonetic representations, the basic phonological system, and basic grammatical structure. Suggestions for dealing with informants, elicitation, and data organization. *Hale*

23.756 *Indo-European* (A)
Prereq.: 23.785
Year: G (2) 3–0–9
Selected topics in the grammar of Indo-European. (*Not offered 1968–69.*) *Kiparsky*

23.758 *Introduction to Linguistics III: Theory of Grammar*
Prereq.: 23.751
Year: G (2) 3–0–9
Elementary transformations and derived constituent structure. Rule government. Variables. Identity. Indexing. The abstract nature of underlying structures. *J. R. Ross*

23.762 *Introduction to Linguistics II: Phonology*
Prereq.: 23.751
Year: G (2) 3–0–5
Aims and principles of a scientific description of the phonic aspect of language. The mechanism and acoustics of speech. Distinctive features as the descriptive framework. The phoneme. The phonemic system of a language. The interrelations between phonology and other linguistic levels. Some problems of historical phonology. Practical exercises. *Halle*

23.766J *Laboratory in the Physiology, Acoustics, and Perception of Speech* (A)
(Same subject as 6.694J)
Prereq.: ——
Year: G (2) 0–6–6
Experimental investigations of speech processes. Measurement of pressure and volume velocity during speech. Interpretation of X-ray motion pictures. Computer-aided analysis and display of acoustic waveforms and spectra, spectrographic analysis, acoustic correlates of distinctive features. Problems in automatic speech recognition; techniques of speech synthesis; studies of speech perception. *Halle, Klatt*

23.768J *Speech Communication* (A)
(Same subject as 6.691J)
Prereq.: ——
Year: G (2) 3–0–9
Survey of structural properties of natural languages with special emphasis on the sound pattern. Survey of physiology of speech production, articulatory phonetics. Acoustical theory of speech production: the vocal tract as a generator of acoustical signals; acoustical correlates of vocal-tract configurations, both stationary and dynamic; acoustical and articulatory descriptions of phonetic features. Perception of speech: the auditory capabilities of man; evidence for perceptual correlates of phonetic categories. Mechanical recognition and generation of speech. Speech transmission and compression; the concept of intelligibility; effects of distortion on intelligibility. Recommended prerequisites: engineering and science students, 6.36T; linguistics students, mathematical background equivalent to 6.05 or 18.05. Others admitted by permission of instructor. *Halle, Stevens*

23.771 *Mathematical Backgrounds for Communication Sciences*
Prereq.: ——
Year: G (1) 3–0–9
Fundamentals of discrete mathematics for non-mathematicians. Introduction to various topics in set theory and foundations, logic and formal systems, modern algebra, theory of automata and computability. *Matthews*

23.772 *Mathematical Models in Linguistics*
Prereq.: 23.771
Year: G (2) 3–0–9
Study of mathematical models that relate to linguistic competence and performance. Formal properties of grammatical systems. Grammars of natural and artificial languages. Models for the speaker and hearer that incorporate representations of his knowledge of the language. Probabilistic models for the user. Stress on interconnections of theory of grammar and theory of automata, and implications for the study of human cognitive processes wherever possible. *Matthews*

23.781 *Survey of General Linguistics I* (A)
Prereq.: 23.751
Year: G (2) *Arr.*
An expository and critical survey of modern structural linguistics. The work of Boas, Sapir, Bloomfield, the Prague Circle, and other developments in general linguistics during the past half-century. Contemporary trends and their immediate backgrounds. (*Not offered 1968–69.*) *Kiparsky*

23.782 *Survey of General Linguistics II* (A)
Prereq.: 23.781
Year: G (1) 3–0–9
Concepts of language as they have arisen in linguistics, psychology, and philosophy studied against the background of developments in science and philosophy. Emphasis on the nineteenth and twentieth centuries, with stress on contemporary relevance. *Chomsky*

23.783 *Topics in the Grammar of Non-Indo-European Languages* (A)
Prereq.: 23.751, 23.754
Year: G (1) *Arr.*
Detailed examination of the grammar of a non-Indo-European language with special emphasis on problems of interest to general linguistics. *Hale*

23.784 *Seminar on Universal Grammar* (A)
Prereq.: 23.752, 23.783
Year: G (1) 3–0–9
Study of grammatical problems in several languages with a view towards achieving a sharper characterization of certain universal features of grammatical structure. *Matthews*

23.785 *Linguistic Change* (A)
Prereq.: 23.751
Year: G (1) *Arr.*
Review of instances of change in phonology, morphology, and syntax. Examples to be drawn from various language families, Indo-European as well as others. An attempt to develop a general theory of linguistic change.
Matthews, Halle, Hale

23.786 *Seminar on Linguistic Change* (A)
Prereq.: 23.785
Year: G (2) 2–0–10
Continuation of 23.785. (*Not offered 1968–69.*)
Hale, Matthews

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. (*Not offered 1968–69.*) *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. (*Not offered 1968–69.*) *Bottiglia*

23.91 *Elementary Russian*
Prereq.: ——
Year: U (1, 2) 4–0–8
Basic grammar. Extensive use of language laboratory. Emphasis on learning to speak as prerequisite for effective reading. *L. H. Scott*

23.92 *Elementary Russian*
Prereq.: 23.91
Year: U (1, 2) 4–0–8
Continued practice in speaking. Selected readings with a dictionary. Conducted in Russian. *Chvany*

23.93 *Intermediate Russian*
Prereq.: 23.92
Year: U (1, 2) 4–0–8
Review of Russian grammar, with the aid of oral and written exercises built around the vocabulary of literary reading material. Work on reading and aural comprehension in the classroom and in the language laboratory.
L. H. Scott

23.94 *Advanced Russian*
Prereq.: 23.93
Year: U (1, 2) 4–0–8
Conversation, reading, and written composition centered on topics of Russian history and culture from the beginning to the present. Use of mechanical devices for improving pronunciation and comprehension.
M. Z. Freeman

23.941 *Introduction to Russian Literature*
Prereq.: 23.94
Year: U (2) 3–0–5
Intensive study of selected masterpieces, combined with introduction to literary terminology and critical method. Conducted in Russian. *Pomorska*

23.95 *Selected Problems in Nineteenth-Century Russian Literature*
Prereq.: 23.941
Year: U (2) 3–0–5
Thorough analysis of the major works of Pushkin, Lermontov, Turgenev, Dostoevski, Tolstoy, and others against the background of the aesthetic and philosophic trends of their era. Conducted in English or Russian, depending on individual student needs and abilities. (*Not offered 1968–69.*) *Pomorska*

23.951* *Soviet Russian Literature*
Prereq.: 21.03 or 21.031 or 21.11 or 23.94
Year: U (1) 3–0–5
Study of the processes which led from the "Golden Age" of Soviet literature to the proclamation of Socialist Realism by the First Congress of Soviet Writers in 1934. Effects of this proclamation on the current situation considered. Authors to be read: I. Babel, B. Pilnyak, I. Ehrenburg, Ilf and Petrov, Sholokov. Readings in English, conducted in English. (*Not offered 1968–69.*)
Pomorska

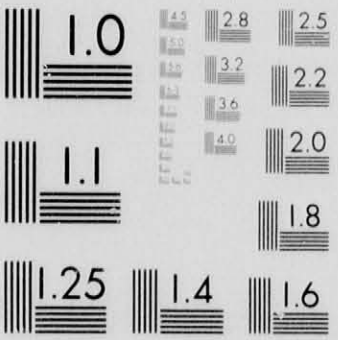
23.96 *Seminar in Modern Russian Poetry*
Prereq.: 23.941
Year: U (1) 3–0–5
Intensive analysis of Russian Symbolist and post-Symbolist poetry up to the Revolution. Conducted in English or Russian, depending on individual student needs and abilities. *Pomorska*

23.961* *Gogol and Literary Methodology in Russia*
Prereq.: 21.03 or 21.031 or 21.11 or 23.94
Year: U (2) 3–0–5
Gogol's writings as approached by sociological criticism (Belinsky, Chernyshevsky), by the symbolists, by the Formalist school; the biographical and psychological approach; the impact of Husserl's phenomenology in Russia at the beginning of the twentieth century. Readings in English, conducted in English. *Pomorska*

23.97 *Scientific Russian*
Prereq.: ——
Year: G (2) 4–0–8
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.*) *M. Z. Freeman*

*Readings in English; conducted in English.

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23.971 ***Intensive Russian I***
Prereq.: ——
Year: G (1) 4–0–8
Introduction to speaking and understanding Russian. No previous knowledge of Russian required. Primary emphasis on rapid acquisition of essentials for effective communication in practical situations. Practice in reading. Full use made of language laboratory. *Staff*

23.972 ***Intensive Russian II***
Prereq.: 23.971
Year: G (2) 4–0–8
Continued training in speaking and understanding Russian. Increased practice in reading. Continued use of language laboratory. *Staff*

23.98 ***Selected Problems in Soviet Literature***
Prereq.: 23.941
Year: U (2) 3–0–5
Intensive study of prose works from the twenties, the "golden age" of Soviet literature, by writers such as young Pasternak, Pilniak, Babel, Zamyatin, Zoshchenko. Followed by readings in prose and poetry of the post-Stalin period, drawn from the works of such writers as Ehrenburg, Panova, Solzhenitsyn, Voznesenskij, Yevtushenko, Okudzhava. Conducted in English or Russian, depending on individual student needs and abilities. (*Not offered 1968–69.*) *Pomorska*

23.981* ***Mayakovsky and Pasternak***
Prereq.: 21.03 or 21.031 or 21.11 or 23.94
Year: U (2) 3–0–5
Consideration of twentieth-century literary movements, like Futurism and Constructivism, through a study of both the poetry and prose of Russia's greatest contemporary poets. Readings in English, conducted in English. (*Not offered 1968–69.*) *Pomorska*

23.99 ***Seminar in Russian Prose***
Prereq.: 23.941
Year: U (1) 3–0–5
Concentrated study of one of the following authors: Gogol, Tolstoy, Dostoevski, Chekhov. Conducted in English or Russian, depending on individual student needs and abilities. (*Not offered 1968–69.*) *Pomorska*

23.991* ***Tolstoi's "War and Peace"***
Prereq.: 21.03 or 21.031 or 21.11 or 23.94
Year: U (1) 3–0–5
Intensive study of *War and Peace* both as an historical novel and a literary structure. Readings in English, conducted in English. (*Not offered 1968–69.*) *Pomorska*

23.993* ***Contemporary Soviet Literature***
Prereq.: 21.03 or 21.031 or 21.11 or 23.94
Year: U (1) 3–0–5
Intensive study of prose and poetry of the post-Stalin period up to the present, based on the works of such writers as Ehrenburg, Panova, Solzhenitsyn, Yevtushenko, Voznesenskij, Okudzhava, Kazakoj, and Aksyonov. Readings in English, conducted in English. *Pomorska*

(See also 21.641 SYMBOLIC LOGIC; 9.59 PSYCHOLOGY OF LANGUAGE AND COMMUNICATION; and 6.574 TRANSMISSION OF INFORMATION.)

*Readings in English, conducted in English.

AS

Aerospace Studies

AS11 ***World Military Systems***
Prereq.: ——
Year: U (1) 3–1–3
Study of historical development of warfare and the causes of present world conflict with emphasis on the role and relationship of military power to the present world situation; concepts and principles of war from which differing political philosophies have evolved; past military policy and its relationship to national power; individual military systems and strategies of all types of warfare, with emphasis upon the U.S. Department of Defense and the U.S. Air Force. Officer leadership training during laboratory periods. (*Restricted to students selected for A.F.R.O.T.C.*) *Brubaker*

AS12 ***Airpower and the World Military Systems***
Prereq.: AS11
Year: U (2) 3–1–3
Continuation of AS11. Political-military issues surrounding the existence of present-day forces; organization, mission, and doctrine of the United States Army, United States Navy, NATO, CENTO, SEATO, and their role in the security of the free world; military forces of the U.S.S.R., the Soviet satellite armies, and the Chinese Communist Army; and effects of the above on military concepts and the world political situation. Officer leadership training during laboratory periods. (*Restricted to students selected for A.F.R.O.T.C.*) *Brubaker*

AS21 ***Aerospace Systems I***
Prereq.: AS12
Year: U (1) 0–1–0
Lecture series on fundamentals of aerospace weapon systems and current concepts for employing U.S. Air Force aircraft and missiles; and continuation of leadership laboratory. (*Restricted to students selected for A.F.R.O.T.C.*) *Staff*

AS22 ***Aerospace Systems II***
Prereq.: AS21
Year: U (2) 0–1–0
Lecture series on concepts and fundamentals of weapons systems and their impact upon the U.S. Air Force; and continuation of leadership laboratory. (*Restricted to students selected for A.F.R.O.T.C.*) *Staff*

AS31 ***Seminar in Growth and Development of Aerospace Power***
Prereq.: AS22
Year: U (1) 3–1–1

AS32 ***Seminar in Growth and Development of Aerospace Power***
Prereq.: AS31
Year: U (2) 3–1–1
Seminar in the development of aerospace power and its relation to the military posture of the United States. Primarily concerned with Air Force concepts, doctrine, and employment, related to astronautical and space operations, with emphasis on future development of aerospace power, both military and civilian. Specific U.S. space programs concerning development of propulsion systems, guidance systems, vehicles and other problems related to space exploration; emphasis on current and projected technology with an introduction into the history of the aerospace power. (*Six weeks of field training is an acceptable prerequisite for AS31 in lieu of AS22. Restricted to students selected for A.F.R.O.T.C.*) *Staff*

AS41 ***The Professional Officer, 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. A study of professionalism, leadership and management. Includes the meaning of professionalism; professional responsibilities; the military justice system; leadership theory, functions, and practices; management principles and functions, problem solving; management tools, practices, and controls. *(Restricted to students selected for A.F.R.O.T.C.)* *Gamache*

AS42 ***Global Geography***
Prereq.: AS41
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. *(Required for students selected for A.F.R.O.T.C.)* *Gamache*

MS
Military Science

MS11 ***World Military History***
Prereq.: ——
Year: U (1) 2–1–1
Analysis of land, sea, and air war in historical perspective, examining the relation of strategy and tactics to geography, economics, sociology, and technology. Examination of the relationship between civilians and soldiers in various forms of government. A survey of the main developments in the history of warfare and applications to current national defense problems. *Staff*

MS12 ***War and the Military Institutions of the Modern State***
Prereq.: ——
Year: U (2) 2–1–1
Examination of the evolution of military institutions of the modern state in the light of the changing forms and modes of war since the eighteenth century. Stress on the interacting relationship between the military institutions of a state and its political institutions and their effect on civil society. *Staff*

MS21 ***National Security and the Concept of Force***
Prereq.: ——
Year: U (1) 2–1–1

MS22 ***National Security and the Concept of Force***
Prereq.: ——
Year: U (2) 2–1–1
Analysis of the capacity of a nation to produce the elements of force from tangible and intangible resources. Effectiveness of force as a means of solving international crises. The various elements of a nation's influence. Role of the military in the maintenance of national security. *Staff*

MS31 ***Concepts and Applications of Military Science***
Prereq.: MS22 or Basic Summer Camp
Year: U (1) 2–1–1

MS32 ***Concepts and Applications of Military Science***
Prereq.: MS31
Year: U (2) 2–1–1
Application of the principles of conventional and unconventional warfare utilizing military systems to develop the junior officer's leadership role; educational psychology and instructional techniques as related through the military man-machine system. Admission to the Advanced Course is restricted to students who have completed the Basic Course (MS11 through MS22) or who complete the Basic Summer Camp, or who have completed at least one year of active military service. *Staff*

MS41 ***Principles and Techniques of Professional Leadership***
Prereq.: MS32
Year: U (1) 2–1–1
Study and application of the principles and techniques of leadership emphasizing management and organization; the study of the junior officer's leadership role in the man-machine system environment. *Staff*

MS42 ***Principles and Techniques of Professional Leadership***
Prereq.: MS41
Year: U (2) 2–1–1
The principles and techniques of military management emphasizing effective and economical utilization of men and materiel; logistics and maintenance; pre-professional instruction in military law, military administration, service life and customs of the service. *Staff*

NS
Naval Science

NS11 ***Orientation and Sea Power***
Prereq.: ——
Year: U (1) 3–1–5

NS12 ***Orientation and Sea Power***
Prereq.: NS11
Year: U (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. *Staff*

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. *Staff*

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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. *Reed*

NS41 ***Naval Industrial Management and Leadership***
Prereq.: NS32
Year: U (1) 3–1–5

NS42 ***Naval Industrial Management and Leadership***
Prereq.: 9.00, NS41
Year: U (2) 3–1–5

Study of the principles and applications of industrial management as applied to naval situations. Topics covered: organization theory, planning and production control, PERT and EPS, time and motion study, personnel and financial management, principles and problems of naval leadership, administration of naval organizations, and related case studies. *Thorson*

SEM

Undergraduate Seminar

SEM11 ***Undergraduate Seminar***
Prereq.: ——
Year: 1 (1, 2) 0–6–0

SEM12 ***Undergraduate Seminar***
Prereq.: ——
Year: 1 (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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APPENDIX A: STUDENT FINANCIAL AID

Scholarships for Undergraduates

A wide range of scholarship assistance is available to undergraduates at M.I.T. All grants are based on an evaluation of financial need and range from small awards to awards up to and including full tuition and living costs. An application for financial aid is an application for assistance from whatever funds the Student Aid Committee may deem appropriate. While a limited number of full-need scholarship grants are made, the great majority of the financial aid awards include some combination of scholarship and loan.

Both these forms of financial aid are in addition to the Deferred Payment Plan and term-time jobs, described in Section 1 of this Catalogue.

The following is an alphabetical list of some of the funds from which scholarship awards are made. The figures in parentheses are 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.

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 and New York. Grants are for the freshman year only and are apportioned according to demonstrated need.

Alcoa Scholarships (1965 and 1968)
Four annual awards of $750, for needy and deserving undergraduate students in architecture, metallurgy, and the information sciences.

AMF Foundation Scholarship (1960)
This two-year grant 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.

Anaconda Scholarships
Two scholarships in the fields of Materials Science and Engineering and Earth Sciences have been made available by the Anaconda Company for children of company employees. First preference will be given to qualified applicants who meet this requirement. Awards will be made by the M.I.T. Committee on Student Financial Aid, employing its usual criteria in the selective process. Stipends will be set in amounts of demonstrated financial need. Awards to Anaconda Scholars are renewable each year subject to performance and in accordance with financial need.

Nils Anderson Scholarship (1961)
This scholarship, founded by a gift and added to by a bequest of Nils Anderson, Founder and Chairman of the Board of Debevoise-Anderson Company, Inc., is intended to assist promising students interested in entering the foundry industry.

William P. Anderson, Jr. Fund (1965)
The income only to be expended for such purposes as the Institute may, from time to time, deem most appropriate, preference to be given to student financial aid.

Louie G. Applebee Fund (1942)
This bequest is "to be expended in assisting deserving students."

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 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 accompanied by documentary evidence that the applicant's father is a regular commissioned officer, active, retired, or deceased.

These scholarships may be renewed upon annual reapplication.

Association of Iron and Steel Engineers — Madsen Scholarship Fund (1966)
The income of this fund, established by the Association of Iron and Steel Engineers as a memorial to Ingvald Elias Madsen '33, is used to support one or more undergraduate students with preference given to those enrolled in the School of Engineering.

Athan Scholarship (1962)
This annual scholarship was established by D. J. Athan '54, for upperclassmen in the Department of Architecture. Demonstrated need and professional competence are the basic criteria for the grant. Selection and recommendations are based in part on nominations made by the Department of Architecture.

Elisha Atkins Fund (1894)
This fund, established by Mrs. Mary E. Atkins of Boston with a gift of $5,000, is used for undergraduate scholarships.

Hattie G. Atkins Fund (1962)
The income of this fund, established by the bequest of Mrs. Hattie G. Atkins in memory of her ancestor, Matthew Gannett, is used to provide not more than two annual grants "to worthy students."

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 from Charles Tidd Baker is "applied each year to the assistance of poor and worthy students."

John Rice Bell Memorial Scholarship (1961)
The income of this fund, established by Kenneth E. Bell '17, in memory of his brother, John Rice Bell '11, is used to assist undergraduate students, preferably in chemical engineering.

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 Aid 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."

Ernst Henri Birmbaum Memorial Fund (1964)
The income of this fund, established by bequest of Mr. David Bingham in memory of his son, is used for one or more scholarships for students in chemical engineering.

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."

Blumcraft of Pittsburgh Scholarship (1962)
An award of $250 is made annually to a student in the Department of Architecture selected by the Committee on the recommendation of the Department.

Levi Boles Fund (1915)
The net income of this bequest 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 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 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 (Mass.)."

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. . . ."

Hubert D. Broderic (1965)
The income of this fund, established by Stuart C. Broderic '47 and Mrs. Guyetta G. Custance in memory of Hubert D. Broderic, is used to provide scholarship assistance to worthy and needy students at M.I.T.; first preference is given to residents of Lexington, Massachusetts.

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."

Denison K. Bullens Scholarship Fund (1958)
A gift of Denison K. Bullens '09, this fund is used to provide scholarships for needy and worthy undergraduates, with first preference to students in metallurgy.

Cabot Corporation Scholarships (1955)
The income of a fund established by the Cabot Foundation, Inc., provides scholarships for children (sons *and* daughters) of employees of the Cabot Corporation 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 the Cabot Corporation and are expected to comply with the usual policies governing the award of Institute scholarships. In any year when there are no applicants admitted to the Institute included as children of employees of the Corporation, the income may be used for scholarships for other qualified applicants for admission to the Institute.

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 (1960)
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.

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.

Mabel Blake Case Fund (1920)
This bequest from Caroline S. Freeman is "known as the 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 Scholarships (1955)
An annual grant from the Chemical Club of New England is awarded to a qualified junior or senior in chemistry or chemical engineering, who resides in New England.

Clapp and Poliak Scholarships (1966)
This annual gift of $20,000 from a fund established by Clapp and Poliak Inc. in honor of the Design Engineering Show Exhibitors, is for undergraduates in the field of design engineering, to provide awards up to full tuition and living expenses.

Lucius Clapp Fund (1905)
This gift from Lucius Clapp formed a fund "to aid worthy students who may not be able to complete their studies without help."

Clark Foundation Scholarships (1953)
This fund, established by the Edna McConnell Clark Foundation, provides scholarships for foreign students entering as freshmen, who would otherwise have insufficient means to allow them to matriculate.

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 an entering freshman.

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 1887 Scholarship Fund (1967)
This fund was established by members of the M.I.T. Class of 1887. Its income is used for undergraduate scholarships.

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 1906 Scholarship Fund (1967)
This fund was initiated by members of the M.I.T. Class of 1906. A portion of the interest is to be used for general purposes, with preference for scholarships.

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.

Class of 1910 Scholarship Fund (1967)
This fund was established by the members of the M.I.T. Class of 1910. The income is to be used for undergraduate scholarships.

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 1932 Fund (1951)
The income from this fund, the twenty-five year gift of the Class, provides undergraduate scholarship grants.

Class of 1933 Fund (1958)
The income of this fund, a gift of the Class at its twenty-fifth reunion, is available for scholarship grants to undergraduates.

Class of 1934 Fund (1959)
The income of this fund, an endowment by the Class as its twenty-five-year gift, provides awards known as the Karl T. Compton Scholarships.

Class of 1938 Scholarship Fund (1938)
The income of gifts from the Class of 1938 is used for scholarships, preference being given those applicants "who have shown their desire for an education by earning part of their expenses; and/or to those applicants who are descendents of the Class of 1938."

Fred L. and Florence L. Coburn Fund (1932)
The income of this bequest from Fred L. Coburn "shall be expended by the 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.

W. A. Conant Scholarship Fund (1943)
This bequest 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."

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." Awards are made to students in metallurgy.

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.

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."

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.

Isaac W. Danforth Fund (1903)
This bequest from James H. Danforth for scholarship purposes was a memorial to his brother, Isaac Warren Danforth.

Tenney L. Davis Scholarship Fund (1967)
This fund, established in memory of Tenney L. Davis '13, is to be used in assisting students with need who show great ability in the study of chemistry.

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. Preference is given to students from Pittsburgh or Sewickley, Pennsylvania.

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 Funds (1956 and 1959)
Established by gifts in memory of Carl Pullen Dennett, these two funds provide awards 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 Student Affairs.

Marie G. Dennett Scholarship Fund (1963)
Established by gift of the Marie G. Dennett Foundation, 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 Student Affairs.

Thomas C. Desmond Scholarship (1952)
Established by the gift of Thomas C. Desmond '09, this scholarship is awarded to qualified students in civil engineering.

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.

Development Fund Scholarships (1950)
Scholarships provided by gifts to the M.I.T. Development Fund consist of grants to students who demonstrate need for financial assistance. They are open to all candidates from secondary schools.

Ann White Dickinson Fund (1898)
This bequest 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."

Frederick N. Dillon, Jr. Scholarship Fund (1968)
The net income of this fund, established by the will of Frederick N. Dillon, Jr. '22, is used for providing scholarships for undergraduate work to deserving students from Fitchburg, Massachusetts, and the immediate area.

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 for scholarship purposes was raised by miscellaneous subscriptions; it was formerly known as Students' Aid Fund.

Henry C. Dresser Fund (1965)
Established from the bequest of Henry C. Dresser '92, the income is used for scholarships, preference being given to students residing in Southbridge, Massachusetts.

Thomas Messinger Drown Scholarships (1928)
A bequest from Mary Frances Drown was designated "to establish scholarships for deserving undergraduate students, to be known as the Thomas Messinger Drown Scholarships."

Charles Dyer Scholarship Fund (1968)
This fund was established by Ira Dyer '49, in memory of his father, Charles Dyer. The income is used for scholarships to undergraduates.

Daniel W. Edgerly Fund (1964)
The income of this fund, established by bequest of Daniel W. Edgerly '98, is used "for the purpose of maintaining undergraduate scholarship aid for upperclassmen in the science departments, preferably in chemistry, physics, or biology."

Edgerton, Germeshausen and Grier, Inc., Scholarships (1955)
This gift provides scholarships, preferably for students in electrical engineering.

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.

Leola M. Farnham Scholarship Fund (1966)
Bequest for the purpose of supporting part tuition or full tuition for undergraduate students in the field of science.

Farnsworth Fund (1889)
This fund was founded by Mrs. Mary E. Atkins of Boston, the income to be used for scholarship purposes.

Alton J. Farrel, Jr. Scholarship Fund (1967)
Income from this fund is used to provide scholarships to students with need who are residents of Ansonia, Connecticut, or its vicinity or to other residents of the state of Connecticut.

Charles Lewis Flint Fund (1889)
This bequest 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 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."

Forging Industry Educational Research Foundation Scholarships (1967)
This fund provides two undergraduate scholarships annually to students in the Department of Metallurgy and Materials Science, with preference given to students showing interest and promise in the field of hot working and hot behavior of materials. Stipends are determined on the basis of demonstrated financial need.

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 management, 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."

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. Three awards are made to entering first-year students. Stipends will be fixed on the basis of demonstrated need.

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 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.

Ethel A. Gleason Memorial Scholarship (1963)
The income of this fund, established as a memorial to Ethel A. Gleason '01, by her nephew, Dr. Anthony H. Gleason, is used to assist worthy and needy undergraduates.

Goodyear Scholarship (1957)
A stipend of $1,000 made available by the Goodyear Tire & Rubber Company Fund is granted to a male U.S. citizen majoring in chemical 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 fund, established by bequest of Barnett D. Gordon '16, is to be used "as scholarships for deserving students at M.I.T."

John H. Gregory Fund (1963)
The income of this fund, established by bequest of Sarah James Gregory in memory of her husband, John H. Gregory '95, is used to provide scholarships for juniors and seniors in civil engineering.

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.

Robert E. Gross — Lockheed Aircraft Corporation Scholarships (1963)
The income of this fund, established by the Lockheed Aircraft Corporation to perpetuate the memory of Robert E. Gross, founder and principal officer of the Corporation for many years, is available to citizens of the United States who are studying in science, engineering, or other fields applicable to the aerospace, electronics, marine, manufacturing, and construction industries.

Rita Welch Gruber Memorial Scholarship (1961)
The income of this Memorial Fund, established by the gift of Rudolf E. Gruber '16, is used to assist undergraduate foreign students to pursue a course of study at the Institute. Grants are available to foreign students in all departments of the Institute, and there are no limitations in fields of study. In its selection the Committee gives first preference to students who are nationals and residents of Germany, Italy, or France.

Gulf and South America Steamship Company Fund (1953)
Fund established by Gulf and South American Steamship Company from which scholarship grants may be made upon initiative of the Department of Naval Architecture and Marine Engineering. Preference is given to students in the course in Shipping and Shipbuilding Management (Course XIII-B).

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.

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.

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."

Claire Morton Prince Hanks Fund (1966)
This fund, established by bequest of Claire Morton Prince Hanks, is to be used for "such purpose connected with financial aid as the Executive Committee may deem appropriate." Awards from this fund are made to undergraduate students who are citizens of the U.S.

Harrington Scholarship Fund (1961)
The income of this fund, established by Joseph Harrington, Jr. '30, in commemoration of his father, Joseph Harrington '96, is used for student aid purposes.

James H. Haste Fund (1930)
This bequest of James H. Haste '96 is "for the aid of deserving students . . . of insufficient means."

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, graduate of the English High School Class of 1886 and of the M.I.T. Class of 1890.

Joseph Hewett '96 Fund (1965)
Established from the bequest of Joseph Hewett '96, the income from this fund is used in maintaining scholarships at M.I.T.; preference is given to students from the public schools of Brockton, Massachusetts.

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 from Rose Hollingsworth founded the 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.

Theodore V. Houser Scholarship Fund (1956)
The fund, established by gifts of Theodore V. Houser, is used for scholarship purposes.

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."

Huguenot Society of America Scholarship (1962)
This annual grant of $1,000 for an M.I.T. undergraduate is provided by the Huguenot Society of America. Applicants must be certified by the Huguenot Society of America as descendants of a Huguenot who came into the territory (now United States) prior to November 28, 1787. The Committee on Student Financial Aid will make a selection from certified and qualified applicants.

Samuel P. Hunt Fund (1945)
This gift of Samuel P. Hunt '95 was designated for scholarship purposes.

T. Sterry Hunt Scholarship (1894)
A bequest 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 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."

Cuthbert Hurd Scholarship Fund (1968)
The income of this fund, established by Cuthbert Hurd, is used for scholarships to students in the mathematical sciences.

John Jay Ide Prize Scholarships (1962)
These six prize scholarships were donated by Mrs. John Jay Ide to honor the memory of her husband, the late Captain John Jay Ide. They are prize awards for the freshman year carrying a fixed stipend of $2,200 and are limited to students who are planning to study aeronautical 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.

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.

David L. Jewell Fund (1928)
The income from this bequest 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 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 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.

Henry Donald Kemp Fund (1964)
The income of this fund is to be used to provide scholarship aid to students in the Department of Electrical Engineering.

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.

Robert M. Kimball '33 Memorial Scholarship (1964)
This fund has been established by the Class of 1933 as a memorial to Robert M. Kimball '33. Awards are made to students with established need, and preference, whenever possible, is given to descendents of the Class of 1933.

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."

Kollsman Instrument Fund Scholarship (1961)
Four annual awards, established by the Kollsman Instrument Corporation, are awarded to outstanding undergraduates in the Schools of Engineering and Science.

Kurrelmeyer Fund (1947)
This fund was raised by contributions by alumni "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.

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."

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 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, . . . be determined by the President of said Institute to be entitled thereto for excellence in scholarship and conduct."

Littmann Foundation Scholarship (1960)
This four-year grant, supplied by the Littmann Foundation, is available 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.

Lockheed Leadership Fund Scholarships (1953)
Established by the Lockheed Leadership Fund, these scholarships are for worthy young men and women who are citizens of the United States. Recipients must be secondary school graduates under twenty-five years of age who plan to major in a field of engineering applicable to the aircraft industry. In the selection for this award, the Student Financial Aid Committee will give recognition to factors other than scholastic achievement. Grants are for full tuition plus $500 toward living expenses, renewable for three additional years — or the total undergraduate period.

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.

Sheridan A. Logan Fund (1964)
A gift of Sheridan A. Logan, the income and principal used as required to provide scholarships to outstanding young men coming from the St. Joseph, Missouri, area.

Elisha T. Loring Fund (1890)
This bequest from Elisha Thacker Loring is for "the assistance of needy and deserving pupils."

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.

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.

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.

Loyal League Scholarships (1959)
Three $1,000 scholarships established by the Loyal League Philanthropies, Inc., are available to entering freshmen, graduates of public

secondary schools in the Greater New York Metropolitan Area, who have demonstrated academic excellence and great financial need.

Samuel E. Lunden Leadership Grant (1968)
From a fund established at the Institute by Samuel E. Lunden '21, a grant is made annually to an entering freshman who evidences the potential of becoming a leader in the affairs of the nation. Recipients are selected primarily on the basis of high personal promise of leadership qualities; stipends are determined on the basis of need. First preference goes to applicants from the territory of the M.I.T. Club of California, second to applicants from the western region of the U.S. Recipients must be U.S. citizens.

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 superior students. First preference is given to students resident in Texas, Arizona, New Mexico, and Oklahoma, desiring to study in the earth sciences or related fields.

Alice Maclaurin Scholarship (1951)
Gifts created a scholarship in memory of Mrs. Richard C. Maclaurin.

Georgia Lamar Malone Scholarship (1961)
Income from this fund, established as a memorial to his mother by Charles B. Malone, Jr. '15, is used for scholarships for undergraduates, with first preference to students from Georgia or the Deep South.

Theodore A. Mangelsdorf Fund (1961)
The income of this fund, established by gift of the Brookdale Foundation, is used to provide undergraduate scholarships.

Francisco Marcucella Fund (1953)
This gift of Francisco Marcucella '27 was designated for undergraduate 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."

Martin-Marietta Foundation Scholarship Fund (1954)
This fund of $25,000 functions as an endowment to provide scholarships for students majoring in fields identified with the operations of the Aerospace Group of the Martin-Marietta Corporation. Students from the Baltimore, Maryland, Washington, D.C., Denver, Colorado, Orlando-Canaveral, Florida, and Vandenberg, California, areas are eligible.

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 male 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.

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."

Thomas Mayor Fund (1963)
The income from this fund is for scholarships to aid worthy and needy young men who are citizens of the United States, with preference given to those of the Protestant Christian faith and of English or Scottish descent.

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 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."

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.

James H. Mirrlees Fund (1886)
This gift 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."

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 to outstanding freshmen 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 and National Scholarship Funds (1955)
The income of these funds 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 fund was initiated by Harold B. Harvey '05 "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."

Morningstar Scholarship (1953)
This undergraduate scholarship gives first preference to students in the Department of Physics. 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 $200 to $2,000 annually, and is offered to young people of superior talent and promise.

Gertrude B. Newman Scholarship (1952)
This bequest from the estate of Mrs. Gertrude B. Newman is to aid worthy and deserving students.

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. 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.

Nichols Scholarship (1895)
This bequest 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 from Charles C. Nichols constitutes a scholarship fund.

Hart and Arthur Nichols Scholarship Fund (1966)
This fund, in process of being established by gifts from W. Hart Nichols '27 and Arthur A. Nichols '28, is to be used for undergraduate scholarships.

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 '97 Scholarships (1956)
The income of a fund established under the will of Catherine B. Noble and enriched by the bequest of Howard A. Noble, is used to maintain scholarships in engineering.

John Felt Osgood Scholarship (1909)
This bequest 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."

Frank E. and Seba B. Payne Foundation Scholarship Fund (1962)
A gift of the Frank E. and Seba B. Payne Foundation is used for scholarships in the School of Engineering.

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 students in the field of sanitary engineering, with second preference to 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 scholarships.

Richard Perkins Fund (1887)
The income from half of this bequest from Richard Perkins is available for the "support of free scholarships in said Institute."

St. Elmo Tower Piza Memorial Fund (1962)
The income of this fund, a bequest of Margaret Piza Crane established in memory of her brother, St. Elmo Tower Piza '15, provides for "tuition or expenses of a man or woman student in any of the five years of the Course in Architecture." The grants are awarded on the basis of scholarly achievement, demonstrated qualities of leadership, and financial need, but entirely without regard to race, color, or creed.

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."

Procter and Gamble Scholarship (1955)
One four-year scholarship, covering tuition plus an added amount for books and supplies, is sponsored annually by the Procter and Gamble Fund. The scholarship is open to all entering students without restriction as to area of study.

George H. Rand Scholarship (1958)
The income of this fund, established by a bequest of the estate of George H. Rand, provides scholarships for deserving undergraduate students.

Thomas Adelbert Read Scholarship (1934)
This bequest 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. . . ."

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."

Arthur Reid Memorial Scholarship (1966)
This fund is available to qualified needy students from the Avon, Massachusetts, community and was established by the Institute as a Memorial to Arthur Reid, who passed away while employed at M.I.T.'s Laboratory for Nuclear Science, assisting with frontier developments in High Energy Physics.

Charles A. Richards Fund (1959)
This bequest is "known as the Charles A. Richards 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.

I. D. Richheimer Memorial Scholarship (1961)
The income of this fund, bequeathed as a memorial by Rose N. Richheimer, is used for scholarships to worthy students.

John Roach Scholarship Fund (1937)
This bequest 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.

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 engineering, science, or architecture. Stipends are awarded according to demonstrated need. These scholarships are open to all freshmen with no restrictions of geographical location.

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 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 of George Scher established a fund to be used for scholarship purposes.

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 Protestant students at the discretion of the Institute.

Louis E. and Theresa Seley Student Aid Fund (1961)
The income of this fund, the gift of Louis A. Seley, provides scholarships for undergraduate students who are needy and worthy.

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.

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."

Thomas Sherwin Scholarship (1871)
Founded with a gift 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.

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 $200 prize scholarships to $2,500 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."

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.

Society of Naval Architecture and Marine Engineering Scholarships (1957)
These grants were established by the Society of Naval Architects and Marine Engineers. Four scholarships, each in the amount of $1000, for students in, or planning to be in the Department of Naval Architecture and Marine Engineering. Preference will be given to secondary school graduates of outstanding promise. These awards may be renewed annually upon application.

Sons and Daughters of New England Puritan Colony Scholarship (1931)
Holders of this scholarship, made possible by a gift 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 is used "in assisting meritorious students."

Standard Oil Company of California Scholarships (1955)
This annual grant, sponsored by the Standard Oil Company of California, is made to a senior in chemical engineering.

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 made available for scholarship aid.

Philip Stockton Fund (1961)
The income from this fund, given in memory of Philip Stockton by Mrs. Philip Stockton, is used for undergraduate scholarships.

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.

Howard F. Taylor Memorial Scholarship Fund (1962)
The income from this fund, donated by students, friends, and associates of Professor Taylor, is used for assistance to undergraduate and graduate students interested in foundry and allied fields.

Lawrence E. Teich '40 Memorial Scholarship Fund (1966)
This fund, established by the Curt Teich Foundation as a Memorial to Lawrence E. Teich, Class of 1940, who gave his life while on active duty during World War II, is used to support the undergraduate scholarship program.

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.

Richard H. Tingey Memorial Fund (1962)
This fund, a gift from the Herman W. Falk Foundation, was established in memory of Richard H. Tingey '27, a noted ship propulsion engineer. Its income provides scholarship grants to undergraduate students.

Samuel E. Tinkham Fund (1924)
Established by the Boston Society of Civil Engineers, this fund is to aid a worthy student in civil engineering.

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 in the junior or senior year 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 from Susan Upham is "to assist students deserving financial aid."

Samson R. Urbino Fund (1927)
This bequest 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 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."

F. P. von Olker Fund (1962)
The income of this fund, established by the bequest of F. P. von Olker, is to be used "yearly in giving scholarships for the benefit of deserving students."

Ann White Vose Fund (1896)
This bequest from Ann White Vose was designated "to establish free scholarships in M.I.T. . . . such person enjoying benefit . . . shall be worthy young men of American origin."

Arthur M. Waitt Fund (1925)
This bequest 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 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.

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.

John J. Watson Memorial Fund (1963)
The income of this fund, given by the Watson Foundation as a memorial to John J. Watson, one of its founders, is for scholarships for needy and deserving 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 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 $1,000.

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 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."

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 residing in the area of the M.I.T. Club of Detroit.

Thomas H. Wiggin '95 Fund (1965)
Established by the bequest of Thomas H. Wiggin '95, the income is used to provide scholarship assistance to needy and worthy students.

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."

Wilson Scholarship (1953)
Gift of John J. Wilson '29 in memory of his parents, the income for scholarships to worthy undergraduates.

Gilbert Williams Winslow Memorial Fund (1967)
A gift from Mrs. Edward Williams Winslow established this fund in memory of her son, Gilbert Williams Winslow '37. The income of this fund is available to assist undergraduates with a preference for students in Civil Engineering.

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 later in 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.

Financial Aid for Graduate Students

Financial aid is available to graduate students from a variety of sources and in a variety of forms — fellowships, traineeships, scholarships, teaching and research assistantships, and loans. A general description of the various sources and forms of aid and of the relevant requirements and application procedures will be found in Section 3 of this Catalogue.

Listed here are fellowships and scholarships which have been generously given by individuals and corporations. About 250 awards are made from these funds each year. A student who files an Application for a Graduate Fellowship, Traineeship, or Scholarship, as explained in Section 3 of the Catalogue, is automatically considered for all of the awards for which he is eligible.

VARIOUS FIELDS

Edward Austin
Bequest of $360,000, the income for needy, meritorious students and teachers to assist them in paying academic expenses.

Joseph Warren Barker
Fellowship for a graduate student in engineering.

Boeing Company
Fellowship for a graduate student in an engineering discipline related to the aerospace industry, with preference given to a student in aeronautical or electrical engineering; tuition plus $2,100.

William Sumner Bolles
Bequest of $25,000 by William P. Bolles in memory of his son, to support a fellowship, travelling scholarship, or resident scholarship, the recipient of which must have character, ability, or promise.

M.I.T. Canadian Trust Fund
A limited number of grants for graduate study leading to advanced degrees in any of the five academic schools for graduates of Canadian universities and colleges who are Canadian citizens. For consideration, an applicant should direct a request by letter to the Executive Officer, Graduate School, M.I.T., prior to *February 15*. Awards will be announced in late March or early April.

Helen Collamore
Bequest of $10,000, the income for aid to women students in postgraduate courses.

Douglas Aircraft Company
For a highly recommended graduate student in aeronautics and astronautics, or electrical, or mechanical engineering; tuition plus not less than $2,100.

Daniel W. Edgerly
Bequest of $240,000 by Daniel W. Edgerly '98 the income for undergraduate scholarships for upperclassmen or for graduate scholarships and fellowships in the Science Departments, preferably in chemistry, physics, or biology.

Alfred Willard French
Founded in memory of Alfred Willard French '89 by the French Oil Mill Machinery Company, for a graduate student in engineering (preferably mechanical) or business administration, with preference to a student from within a 100-mile radius of Piqua, Ohio.

Frank M. Greenlaw
Bequest of $74,000 by Frank M. Greenlaw '90 the income to establish a fellowship for research in physics or chemistry or related fields of learning.

Joint Center For Urban Studies
Doctoral fellowships to graduate students in any department of either Harvard or M.I.T. writing a doctoral dissertation on any aspect of urban life, in fields such as: government, science and engineering, social relations, design, economics, planning, history, law, or industrial management; award including stipend up to $5,500.

John A. Lyons
Under the will of the late John A. Lyons, five or more fellowships will be available in 1967 and subsequent years for the support of graduates of Boston College, subject to the following provisions: the recipients must be of the Roman Catholic faith; they must have been born within a radius of 20 miles of the Massachusetts State House; preference will be given to applicants whose father and mother were of Irish descent; the fellowships are only for those who do not consume alcohol in any form; they must live at the Institute during the academic year. The fellowships will cover tuition and will provide a stipend to help meet living expenses. They will be renewable from year to year.

Henry Bromfield Rogers
Bequest of $20,000 by Anna Perkins Rogers, the income for a fellowship or scholarship for women graduates of M.I.T. or other colleges whose graduate work is carried on at M.I.T.

Henry Saltonstall
Bequest of $10,000, the income to aid one or more needy students.

James Savage
Bequest of $10,000, the income for scholarships in the institution "where my son-in-law, William B. Rogers, is President."

Solar Energy
Four fellowships for graduate students, candidates for the doctorate in chemistry, physics, or engineering or candidates for the degree of Master in Architecture, for study and research which may lead to improved use of solar energy; tuition plus $2,100, with dependency allowance for a married student; normally for two terms but renewable.

Susan H. Swett
Bequest of $10,000, the income to support a graduate scholarship.

Gerard Swope
Gift of $100,500 by Gerard Swope '95, the income to support fellowships for graduate students of exceptional ability and promise.

Thomas Upham
Bequest of $409,000 by Marcella B. Upham, the income for assisting poor and deserving students or graduates of the Institute.

Jonathan Whitney
Bequest of $525,000 by Mrs. Francis B. Green, the income to assist poor and deserving young men and women in obtaining an education at M.I.T.

Hugh Hampton Young Memorial Fund
A fund in memory of Dr. Hugh Hampton Young to provide premium financial assistance to outstanding students with exceptional breadth of interests who show great promise of becoming capable and efficacious directors and co-ordinators of broad projects covering many disciplines and who are selected with great discrimination and with more consideration given to personal qualities and character than to scholastic record. Open to undergraduate, graduate and postdoctoral students.

AERONAUTICS AND ASTRONAUTICS

AC Electronics Fellowship
For a graduate student in instrumentation; tuition plus $2,100.

Aviation Week
For a male U.S. citizen enrolled for an advanced degree; tuition plus $2,100.

Bendix Corporation
For an outstanding graduate student in automatic controls or control system components; tuition plus not less than $2,100.

Donald W. Douglas
Gift of $73,725 in honor of Donald W. Douglas '14, Chairman of the Board of the Douglas Aircraft Company, the income to be used to support deserving graduate students in aerospace and related fields.

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 $2,100.

Lester D. Gardner
Fellowship in memory of Lester D. Gardner '98; tuition plus $2,100.

General Dynamics
For a graduate student in aeronautics and astronautics; tuition plus not less than $2,100.

Lockheed Leadership Fund
For a graduate student in the field of aerodynamics; tuition plus not less than $2,100.

ARCHITECTURE AND PLANNING

Avalon Foundation
Gift of $250,000, the income to support fellowships and scholarships for graduate students in the School of Architecture and Planning.

W. Danforth Compton Memorial
Gift of $90,000 in memory of W. Danforth Compton '47, the income to support fellowships in the Department of Architecture.

William Emerson Fund
The income of the bequest of $29,000 of the late William Emerson, Dean of the School of Architecture, is used for fellowships in the Department of Architecture.

William Emerson
Gift of $5,000 by Dean William Emerson, the income to support graduate students in City Planning.

William and Frances Emerson
Gift of $100,000, the income to aid graduate and special students in the School of Architecture and Planning.

William E. Hartmann Scholarships (1962)
This fund was established to assist students in architecture who hold baccalaureate degrees from an institution not offering professional architectural studies. Awards may be made for the first year at the Institute.

Samuel A. Marx
Established by gifts of $33,900 in memory of Samuel A. Marx '07, the income for an annual fellowship in the School of Architecture and Planning.

Richard King Mellon Foundation
Fellowships for graduate work in City Planning and Urban Renewal.

CHEMICAL ENGINEERING

American Cyanamid Company
For several graduate students in chemical engineering for one term each in the School of Chemical Engineering Practice; tuition plus $500.

R. R. M. Carpenter
Tuition plus $1,400.

Crown-Zellerbach Foundation
For a graduate student who shows achievement and promise in the profession of chemical engineering; tuition plus $2,100.

Eastman Kodak Company
Two fellowships for graduate students in chemical engineering; tuition plus $2,500.

Esso Research and Engineering Company
For a graduate student in chemical engineering; tuition plus $1,800 single, $2,100 married, $2,400 married with dependent children.

Arthur D. Little
Fellowship in memory of Arthur D. Little '85, for a candidate for a doctorate; tuition for two regular terms and one summer term plus $2,100.

Procter and Gamble Company
For a graduate student in chemical engineering; 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.

Sun Oil Company
Summer fellowship for graduate students of American citizenship; tuition plus $600.

Union Carbide Chemicals Division Practice School
For a student who attends the School of Chemical Engineering Practice for one, two, or three terms; tuition plus $1,800 single, $2,100 married, per twelve-month period.

Union Oil Company of California Foundation
For several graduate students in Chemical Engineering for one term each in the School of Chemical Engineering Practice; tuition plus $500.

CHEMISTRY

Lewis Paul Chapin
Bequest of $100,000 by Mrs. Mary Richardson Chapin in memory of her husband Lewis Paul Chapin, formerly Assistant in Inorganic Chemistry, the income to assist worthy postgraduate students in the Department of Chemistry.

E. B. Hershberg Predoctoral Fellowship
Established in honor of Dr. E. B. Hershberg '29 of the Schering Corporation as "a testimonial in recognition of his many and diverse talents, his capacity as a human being, and the catholicity of his intellect and interests."

Arthur D. Little
Fellowship in memory of Arthur D. Little '85, for a candidate for a doctorate in chemistry; tuition plus $2,800 for 12 months.

Minnesota Mining and Manufacturing Company
For a graduate student in chemistry; tuition plus $2,100.

Forris Jewett Moore Memorial
Gift of $24,000 by Mrs. Forris Jewett Moore in memory of her husband, formerly Professor of Organic Chemistry, the income to assist a graduate in his studies at M.I.T. or elsewhere with preference given to a student in organic chemistry; tuition plus $2,100.

James Flack Norris
Bequest of $65,000 by James Flack Norris, formerly Professor of Organic Chemistry, the income to support a graduate fellowship; tuition plus $2,100.

Procter and Gamble Company
Tuition plus $2,100 single; tuition plus $2,500 married.

Union Carbide Corporation
For a graduate student in his final year of predoctoral study; tuition plus $1,800 single, $2,100 married.

CIVIL ENGINEERING

Goodyear Tire and Rubber Company
Fellowship for a graduate student in civil engineering in the field of materials; tuition plus $2,300.

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 graduate or undergraduate.

ECONOMICS

Center for International Studies
For graduate students interested in economic development and international economics; 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 not less than $1,000.

Joseph N. Scanlon
In memory of Joseph N. Scanlon, formerly a Lecturer at M.I.T. in industrial relations; tuition plus not less than $1,000.

ELECTRICAL ENGINEERING

Grass Instrument Company
An endowment established by the Company and Dr. Albert M. Grass '34, the income for fellowships in electrical engineering, preferably for foreign students. Awards are made as often as sufficient income has accumulated to provide an appropriate grant to a student.

Schlumberger Foundation
For a graduate student in electrical engineering; tuition plus not less than $2,500.

MANAGEMENT

Sloan School of Management
For college graduates seeking the Master's or doctor's degree who have demonstrated substantial academic competence and leadership promise. A number of fellowships and scholarships.

United States Steel Foundation
A graduate fellowship for a U.S. student in the area of management; tuition plus $2,400.

MATERIALS

American Can Company
For a predoctoral student in his first or second year of graduate study in materials or in other research fields of interest to the American Can Company; tuition for 12 months plus $2,800, with $400 for one dependent child or $600 for two dependent children. May be prorated for 9 months; renewable for one year.

MECHANICAL ENGINEERING

Cummins Engine Foundation
For a U.S. citizen and full-time student preferably working toward a doctorate; tuition for 12 months plus $2,800 single or married with no children, $3,200 married with children. Stipend prorated for 9 months.

The Camille and Henry Dreyfus Foundation, Inc.
For a candidate for the M.S. or the doctorate in Mechanical Engineering with research interest in fibrous materials. Tuition plus $2,000 single, for 9 months.

Wilfred Lewis
Gift of $5,000 by Mrs. Emily Sargent Lewis in memory of Wilfred Lewis '75, the income to be applied for the support of a graduate student in Mechanical Engineering.

METALLURGY AND MATERIALS SCIENCE

Allegheny-Ludlum Steel Corporation
For a graduate student whose thesis research is on a topic of interest to the alloy steel industry; tuition plus stipend.

American Metal Climax Foundation
For a graduate student whose research is in the general area of the deformation and fabrication of copper and its alloys; tuition plus stipend.

Fairchild Camera and Instrument Corporation
For a graduate student, preferably in physical metallurgy; tuition plus $2,250.

Forging Industry Educational and Research Foundation
For a graduate student in metallurgy and materials science whose research is in the general field of hot plasticity; tuition plus $2,250.

General Telephone and Electronics Laboratories, Inc.
For a graduate student in the field of electronic materials; tuition plus stipend.

International Copper Research Association, Inc.
For a graduate student whose research is in the field of copper-base alloys; tuition plus $2,250.

International Nickel Company
For a graduate student in the field of materials science and engineering; tuition plus $2,250.

Kennecott Copper Corporation
For a graduate student in metallurgy and materials science; tuition plus $2,250.

National Steel Corporation
For a graduate student in metallurgy and materials science whose research is in the general field of the plastic behavior of steel; tuition plus $2,250.

Titanium Metals Corporation of America
For a graduate student working in the field of deformation processing; tuition plus $2,250.

United States Steel Foundation
For a U.S. student in the field of metallurgy; tuition plus stipend.

Vasco Metals Corporation
For a graduate student in physical metallurgy; tuition plus $2,250.

NAVAL ARCHITECTURE AND MARINE ENGINEERING

General Dynamics Corporation
A fellowship for graduate study in Naval Architecture and Marine Engineering; tuition plus $2,100 for two terms, and an allowance for thesis expense.

Gulf and South American Steamship Company
Fund established by Gulf and South American Steamship Company from which scholarship grants may be made upon initiative of the Department of Naval Architecture and Marine Engineering. Preference is given to students in the fifth year in Shipping and Shipbuilding Management (Course XIII-B).

NUCLEAR ENGINEERING

General Electric Foundation
For a graduate student in nuclear engineering; tuition plus $1,800 single, $2,500 married.

NUTRITION AND FOOD SCIENCE

Bernard E. Proctor Memorial
Scholarship in memory of Professor Bernard E. Proctor '23, formerly head of the Department; tuition.

PHYSICS

Fairchild Foundation Fellowship in Applied Physics
For a U.S. citizen or permanent resident in the field of applied physics; tuition plus $2,400 for nine months and allowances.

Kennecott Copper Corporation
For a graduate student in physics; tuition plus not less than $1,800 single or married without children, $2,000 married with one or more children.

RESEARCH LABORATORY OF ELECTRONICS

Hughes Aircraft Company
For graduate work in electronics; tuition plus $2,100 single, $2,700 married.

Radio Corporation of America
For graduate work in electronics; tuition plus $2,100 single, $2,700 married.

Sperry Rand Corporation
For graduate work in electronics; tuition plus $2,100 single, $2,700 married.

Xerox Corporation
For graduate work in information science; tuition plus $2,100 single, $2,700 married.

Student Educational Loan Funds

Low-interest loans are available to both graduate and undergraduate students at M.I.T. The amount of any loan granted by the Student Aid Committee is based on financial need. Information about how financial need is determined and the procedure for application will be found in this Catalogue: Section 2 for undergraduates and Section 3 for graduates.

TECHNOLOGY LOAN FUND (TLF)

M.I.T.'s Technology Loan Fund, established in 1931, was the first major loan fund established by a college; today it is the nation's largest. Since its founding, M.I.T. students have benefited from more than $10,000,000 in loans from this fund. Awards are made on the basis of financial need; and in the interest of its students, M.I.T. sets reasonable limits on the annual amounts borrowed from this fund, and on the total indebtedness accumulated by each borrower.

NATIONAL DEFENSE STUDENT LOAN (NDSL) FUND

M.I.T. also administers loan awards under the National Defense Student Loan Program, using need criteria established by the Student Aid Committee, and eligibility criteria established by the U.S. Department of Health, Education and Welfare. The maximum loan available to an undergraduate from this program for any one academic year is $1,000; no undergraduate may borrow more than a total of $5,000. Graduate students are limited to $2,500 per year, and the total borrowed by any student during his undergraduate and graduate term of study cannot exceed $10,000.

REPAYMENT TERMS

The repayment rate on M.I.T. educational loans (whether from the Technology Loan Fund or from the NDSL Fund, or combinations of both) will be established in each case by M.I.T. on graduation or termination of enrollment. The normal repayment rate required on Technology Loan Fund notes is $300 every six months after graduation. NDSL regulations established by the Federal government state a maximum repayment period of ten years on NDSL notes. The regulations further outline a minimum annual repayment of $180 on these notes. For students with both TLF and National Defense Student Loans, not exceeding $6,000, a $600 maximum annual repayment rate will apply, provided that government regulations permit.

Repayment commences six months after graduation. A student may apply for deferment of repayment if he enters a graduate school, military service, or the Peace Corps. (A maximum of three years' deferment is allowed in the latter two cases.) Up to one-half of loan notes under the NDSL Program may be forgiven if the borrower chooses a career in teaching. Loans carry no interest while the student is enrolled, and three per cent is charged on the unpaid balance during the repayment period.

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 no separate application need be made.

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.

Anna J. and Francesco Casaretto Loan Fund (1966)
Established in memory of Anna J. and Francesco Casaretto, to be operated as a loan fund for the benefit of needy and worthy students, regardless of race, creed or color.

Francis W. Chandler Loan Fund (1927)
This fund was established as a loan fund to assist worthy and needy students in the Department of Architecture.

Ruth Hornblower Churchill Memorial Loan Fund (1958)
Established by a gift in the name of Ruth Hornblower Churchill, this loan fund is used to help needy students at M.I.T.

Class of 1917 Loan Fund (1937)
The income and principal of this fund is used to assist deserving students, preference given to direct descendents of members of the Class of 1917. Beneficiaries are expected to issue notes agreeing to repay the face value, without interest, of amounts received.

Class of 1963 Loan Fund (1963)
This fund, established by the members of the M.I.T. Class of 1963, is used as a source of short-term emergency and special-use funds, without some of the restrictions associated with the Institute's educational loan funds. Repayment is expected before graduation in most cases; where appropriate the repayment period may be extended to one year beyond graduation. Preference is given to undergraduates.

Thomas F. and Lida Niles Connors Loan Fund (1962)
Established by the bequest of Lida Niles Connors, the principal and income of this fund is available to "qualified and deserving students who are undergraduates in Civil Engineering." Procedures of the Technology Loan Fund are followed in granting loans.

Ethel I. Fryer Scholarship Loan Fund (1951)
This fund was a gift of Herbert Fryer '11 to establish a loan fund 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 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.

Gerald L. Hartstein Memorial Loan Fund (1963)
The principal and income of this memorial fund, established at the request of Mr. Hartstein's mother, are available for loans to undergraduates.

John A. Herlihy Loan Fund (1962)
This commemorative fund was established by gift of the United Air Lines Foundation in honor of John A. Herlihy '27, Senior Vice President of United Air Lines. Grants from this fund, limited to undergraduates in the field of aeronautics and astronautics, are administered in the same manner as those from the Technology Loan Fund.

Rebecca R. Joslin Loan 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.

Klock-Overton-Mills-Roberts-Longyear Loan Fund (1961)
This loan fund, established by Felix S. Klock '36, on the 25th anniversary of his graduation from M.I.T. in recognition of the people who significantly influenced and guided him in his education, functions on the same basis as the Technology Loan Fund. In granting awards, the Committee gives preference to needy and worthy students who are children of the employees of the Klock Corporation.

Lamson-Virgin Loan Fund (1946)
This bequest 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.

Harry J. and Iolia R. Lohbiller Loan Fund (1962)
This fund was established by trusts created by Harry J. '01 and Iolia R. Lohbiller. Loans are restricted to juniors and seniors and in certain instances to sophomores.

George H. May Loan Fund (1914)
A gift from George H. May '92 provides a fund "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 Headmaster of the Newton High Schools." Beneficiaries under this fund are expected to issue notes agreeing to repay, without interest, the amounts received.

Helen and Leo Mayer Loan Fund (1967)
Established by a gift of the Helen and Leo Mayer Charitable Trust, the principal and interest of this fund are administered in the same manner as those from the Technology Loan Fund.

George J. Mead Loan Fund (1951)
This bequest of George J. Mead '16 is for loans to upperclassmen in aeronautics and astronautics and mechanical engineering.

Arthur T. Nelson, Jr. Memorial Loan Fund (1962)
Established by a gift of Mrs. Arthur T. Nelson and the Trustees of Arthur T. Nelson, Jr., this fund is used for loans administered under the regular procedures adopted by the Institute to students residing in certain states.

Michael Joseph Pollock Loan Fund (1962)
The income of this memorial fund, established by the parents, relatives, and friends of Michael Joseph Pollock '59, is available for loans to deserving students.

Ellen H. Richards Loan Fund (1964)
This fund, established by a gift from the Eastern Massachusetts Home Economics Association as a memorial to Ellen H. Richards, is used to provide loans, preference being given to women students in chemistry relating to food processing and food technology.

M. H. Rogers Loan Fund (1945)
This bequest of Minnie Hempel Rogers '90 is for loans to worthy students.

Lillie C. Smith Fund (1965)
Income from this fund in memorial of an early alumna is administered by the Association of M.I.T. Alumnae for aid to women students.

Technology Matrons Loan Fund (1960)
This gift of the Technology Matrons is used to assist needy and worthy students with loans.

Robert Kelley Thulman Loan Fund (1963)
The gift of the wife of Robert Kelley Thulman '22, this fund is designated for loans to students.

Timbie Memorial Fund (1954)
This fund was established by graduates of the Cooperative Course in Electrical Engineering (VI-A) in the name of William H. Timbie. It is used to provide loans for students in the Cooperative Course.

F. B. Tough Fund (1924)
Established by a gift of Mr. F. B. Tough, this fund is used to provide loans "for the purpose of extending financial assistance to worthy students while pursuing their courses."

Frank P. Wakefield Loan 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: 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 Student Affairs or by the departments or organizations concerned.

Alpha Chi Sigma Prizes (1965)
Two prizes of $250 each are awarded annually to seniors in recognition of distinguished scholastic achievement, originality, and breadth of interest in chemistry and closely related fields.

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.

Association of M.I.T. Alumnae Award (1958)
This cash award is given to one or more outstanding women students in the junior class.

Avery Allen Ashdown Award
Awarded to a resident of the Ashdown House who carries on the tradition and spirit of service through participation in the affairs of the House.

Baton Society Awards (1960)
These awards are given to seniors for outstanding contributions to music at M.I.T.

Robert A. Boit Prizes (1921)
These annual prizes are made "to stimulate the interest in the best use of the English language." They are awarded to undergraduates on the basis of essays and imaginative works submitted by them. 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 best academic record 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.

The Frederick Gardner Fassett, Jr. Award
Awarded to a member of the Interfraternity Conference, for qualities of spirit, dedication, and service in furthering the ideals of the M.I.T. fraternity brotherhood.

The Goodwin Medal
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 award is 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.

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.

The Eastman Kodak Scientific Awards
Cash Prizes of $1,000 are offered to two doctoral students, one each in chemical engineering and chemistry, on the basis of outstanding contribution and progress, either in graduate studies and research or in teaching.

Military Prizes
A number of individual prizes are awarded to selected outstanding cadets in the Departments of Air, Military, and Naval Science on the basis of technical and professional proficiency.

Outstanding Freshman Award
This award is made to recognize distinguished scholarship, integrity, breadth of interests, adaptability, and high degree of unselfish activity toward the community at large. It is presented by the M.I.T. chapter of the Tau Beta Pi association, National Engineering honorary.

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 terms of freshman chemistry, over-all ability, interest, and promise.

Phi Lambda Upsilon Sophomore Award
This award is given annually to an outstanding sophomore who has demonstrated academic achievement and professional promise in pure and applied chemistry.

Scott Paper Foundation Leadership Award
This award of $1,500 is made annually to a student in the spring of his junior year for senior and first-year graduate study. It is presented in recognition of demonstrated high character, actions on behalf of the welfare of colleagues, and potential for making outstanding contributions to the professional aspects of engineering in business or industry.

William L. Stewart, Jr. Awards (1964)
These awards are given to individual students and student groups for outstanding contributions to extracurricular life. They are made from an annual gift by the W. L. Stewart, Jr. Foundation in memory of Mr. Stewart, member of the Class of 1923, member of the M.I.T. Corporation from 1952 to 1963, and long-time friend and benefactor of the Institute.

Stratton Prizes (1930)
Awards presented yearly for outstanding skill in organized debating. They are made possible by the income of a fund established by the late President Samuel W. Stratton.

AERONAUTICS AND ASTRONAUTICS

Luis de Florez Awards (1960)
The late Admiral Luis de Florez, distinguished engineer and alumnus of the Department of Mechanical Engineering, Class of 1911, endowed awards totaling $1,000 or more to recognize "original thinking or ingenuity" demonstrated by students in Aeronautics and Astronautics.

James Means Memorial Prize (1925)
A medal and monetary prize of $100 or more is offered annually to a senior for excellence in systems engineering.

Henry Webb Salisbury Memorial Award (1941)
Established by the family and friends of Henry Webb Salisbury '33, this award, consisting of books chosen by the recipient, is given for 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.

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.

ATHLETICS

Athletic Awards
In addition to varsity letters and freshman numerals in 20 intercollegiate sports, a number of awards are given to undergraduates by student organizations for outstanding contributions to intramural and intercollegiate athletic activities.

Class of 1948 Award
Established by the Class of 1948, this award is given annually to the member of the graduating class who has best combined the traits of leadership and character with excellence in athletic performance.

Admiral Edward L. Cochrane Award
This award, made possible by Mrs. Cochrane in memory of her husband, is given to a member of the graduating class, participant in the intercollegiate athletic program, who has shown qualities of humility, leadership, and scholarship.

Eastern College Athletic Conference Merit Medal
This medal, established by the Conference to be awarded by its member institutions, gives recognition to an athlete for scholarship and athletic achievement.

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 $100 is made to the most meritorious senior who has shown outstanding originality in his work in the regular Course in Chemical Engineering.

CIVIL ENGINEERING

A.S.C.E. Student Chapter Scholarship
Funds under this award are provided through the gift of Samuel Tapman as a scholarship given annually to an outstanding undergraduate who is a member of a Student Chapter of the American Society of Civil Engineers in A.S.C.E. Zone 1.

Tucker-Voss Award (1953)
Gift of the alumni and friends of the late Professors Ross F. Tucker and Walter C. Voss, former heads 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.

Richard Lee Russel Prize (1967)
This scholarship award of $500 for graduate study in civil engineering at M.I.T. is for an outstanding senior selected by the faculty of the Department. The award is supported by the Richard Lee Russel '89 Fund established in 1904 by Mr. Theodore E. Russel.

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. 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.

Morris J. Levin Award
Award to juniors in electrical engineering who have demonstrated excellent performance through independent work in an undergraduate laboratory project.

Supervised Investors' Services, Inc., Awards (1957)
Four prizes of $500 each are awarded to graduate students who are members of the teaching staff of the Department of Electrical Engineering. They are given to honor those who have demonstrated an interest and proficiency in the field of teaching and to help defray the expenses of graduate study for advanced degrees.

Carlton E. Tucker Awards for Excellence in Teaching (1962)
Two prizes of $500 each, awarded to graduate students who are members of the teaching staff of the Department of Electrical Engineering, are given to honor those who have demonstrated an interest and proficiency in the field of teaching and to help defray the expenses of graduate study for advanced degrees. The Awards honor Professor Carlton E. Tucker, the Department's Executive Officer for 24 years, for his dedication to and interest in high teaching standards; they are supported in part from funds given in memory of Professor Tucker and Professor William H. Radford.

MANAGEMENT

The Brooks Prize in Management

The E. P. Brooks Master's Thesis Prize of $100 is awarded each year for the thesis judged to be the best submitted for the Master of Science in Management. Nominations may be made by the chairman of any Master's Thesis Committee to the Sloan School of Management's Prize Committee.

Editorship of the Industrial Management Review

The editorship of the journal of the Sloan School of Management is awarded annually to selected graduate students in management who have achieved distinguished records of scholarship and leadership in the School.

Sloan School of Management Senior Prize

This annual award of $100, established through the generosity of Samuel Berke, '15, is made to an outstanding senior student in the field of management with high scholastic standing, leadership, and professional promise.

MECHANICAL ENGINEERING

American Society of Mechanical Engineers Student Paper Awards

This contest for outstanding professional papers by student members of A.S.M.E. is sponsored by the local chapter. Prizes totaling about $60 are awarded, and local winners are eligible for regional and national contests.

Luis de Florez Awards (1957)

The late Admiral Luis de Florez, distinguished engineer and alumnus of the Department of Mechanical Engineering, Class of 1911, endowed these awards to recognize "outstanding ingenuity" demonstrated by students in mechanical engineering. Prizes totaling $1,000 or more are awarded each year.

Silent Hoist and Crane Company Materials Handling Award (1950)

These annual prizes, totaling more than $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.

Ed Wellech — Corning Glass Works Award

This award is to be given to students in the Mechanical Engineering sophomore subject Engineering Design and Manufacturing, 2.861. An aggregate of $250 is awarded for the best design project (or projects) and an equal aggregate for the best manufacturing project report (or reports) submitted during each year.

METEOROLOGY

The Carl-Gustav Rossby Award in Meteorology

This award was established, in part, by the gift of Julius Honig '53 in memory of Professor Carl G. Rossby who established the course in meteorology at M.I.T. The award of $100 is made in any year for the most outstanding graduate thesis submitted to the Department of Meteorology.

METALLURGY AND MATERIALS SCIENCE

Dow Chemical Company Prize (1962)

Prizes are awarded, from a $500 gift by the Dow Chemical Company, for the best theses submitted for the degree of Bachelor of Science in Metallurgy and Materials Science.

Metallurgy and Materials Prize (1963)

The sum of $150 is awarded to an outstanding junior in the Department. The award was established by graduate students and associates of Professor Morris Cohen in recognition of his significant contributions to undergraduate education in materials. It is presently supported by the Boston Section, A.I.M.E.

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.

Brand Award (1957)

This award, in memory of Rear Admiral Charles L. Brand, U.S. Navy Class of 1915, is made annually by the American Society of Naval Engineers to the student officer in the graduating class who attains the highest scholastic average in the Course in Naval Construction and Engineering (XIII-A).

NUCLEAR ENGINEERING

General Electric Awards in Nuclear Engineering

A cash award, in amount between $150 and $500, is made each year to one or more graduate student assistants in recognition of outstanding contributions to the teaching or research activities of the Department of Nuclear Engineering.

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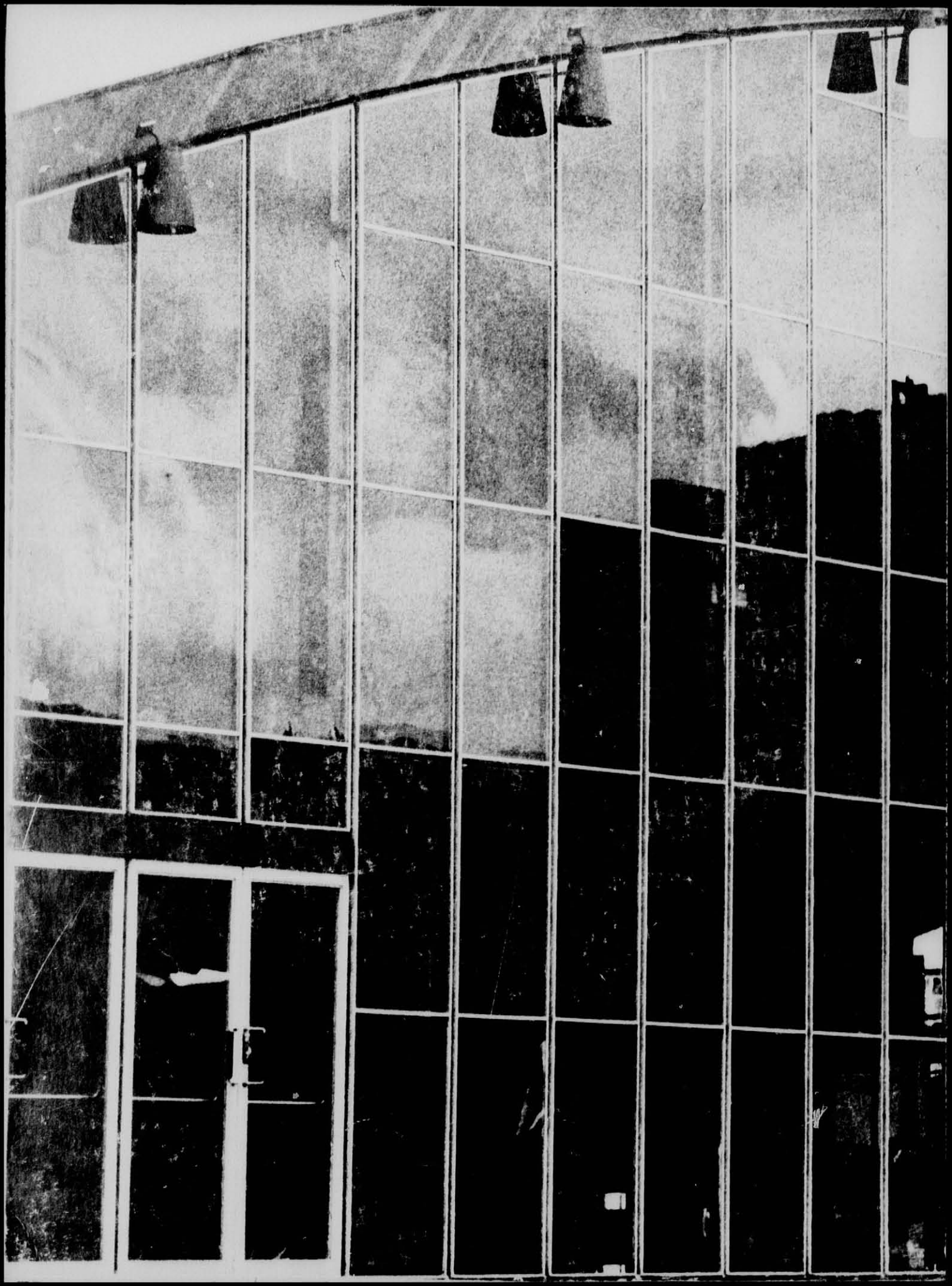
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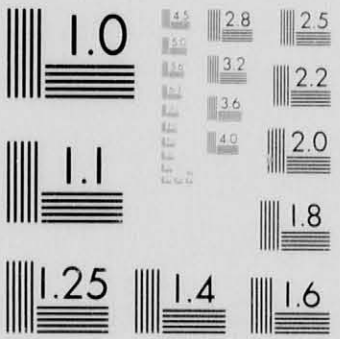
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